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Commencement Bay Nearshore/Tideflats Remedial Investigation. Potential Remedial Technologies

Tetra Tech, Inc., Bellevue, WA

Prepared for

Washington State Dept. of Ecology, Olympia

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POTENTIAL REMEDIAL TECHNOLOGIES FOR THE COMMENCEMENT BAY NEARSHORE / TIDEFLATS REMEDIAL INVESTIGATION

AUGUST, 1985

PREPARED FOR:
WASHINGTON STATE DEPARTMENT OF ECOLOGY
AND U.S. ENVIRONMENTAL PROTECTION AGENCY

Mr. James D. Krull, Project Manager
Washington State Department of Ecology
Olympia, Washington

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Final Report

COMMENCEMENT BAY NEARSHORE/TIDEFLATS REMEDIAL INVESTIGATION

Task 6 Report

POTENTIAL REMEDIAL TECHNOLOGIES

by

Tetra Tech, Inc.

for

Washington State Department of Ecology
and U.S. Environmental Protection Agency

Mr. James D. Krull, Project Manager
Washington State Department of Ecology
Olympia, Washington

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Tetra Tech, Inc.
11820 Northup Way, Suite 100
Bellevue, Washington 98005

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11820 Northup Way, Suite 100
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This report draws on the entire Commencement Bay Superfund Investigation, including assessments of chemical contamination, biological effects, toxicity, public health concerns, and source identification. Potential remedial technologies and actions for contaminated sediments and source control are presented. A description of the waterway segments considered to be problem areas, a discussion of contaminants of concern and their potential sources, and remedial actions that should be screened and evaluated during the Feasibility Study are included. This report is Task 6 of the U.S. EPA/WDOE Cooperative Agreement for the Commencement Bay Superfund Investigation.

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The primary author of this report was Ms. Glynda Steiner. Individuals contributing to the research, evaluation, and report writing efforts are listed below.

Tetra Tech, Inc. Technical Staff

Mr. Robert C. Barrick	Sediment Chemistry, Waterway Ranking
Ms. Marcy B. Brooks-McAuliffe	Technical Editor
Dr. Thomas C. Ginn	Management, Review
Mr. Thomas L. Johnson	Remedial Technologies, Review
Dr. Marc W. Lorenzen	Management, Quality Control, Review
Mr. Larry Marx	Regulatory Policies, Feasibility Study Work, Plan, Project Coordination
Ms. Glynda Steiner	Remedial Technologies, Waterway Descriptions, Applicable Methods Case Study
Ms. Theresa Wood	Technical Editor

Production Staff

Mr. A. Brian Carr	Graphics
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1.0 INTRODUCTION

1.1 BACKGROUND

In 1981, U.S. EPA announced an "interim priority list" of 115 top-priority hazardous waste sites targeted for action under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), also known as "Superfund." Commencement Bay, located in the southern Puget Sound region, was listed as the highest priority site in the state of Washington and one of the 10 highest national priority sites for federal funding of remedial action under CERCLA. The Commencement Bay site was divided into four areas: the Deepwater, the Nearshore, the Tideflats Industrial, and the South Tacoma Channel.

On December 30, 1982, U.S. EPA proposed additions to the national priority list. The list increased to 418 hazardous waste sites ranked by their potential threat to public health and the environment. On this subsequent Superfund list, the Nearshore and the Tideflats Industrial areas were designated as a separate project, as was the South Tacoma Channel. The Deepwater area was eliminated as a priority site because water quality studies indicated less contamination in that area than was initially suspected. On September 6, 1983, U.S. EPA published and promulgated the first official National Priority List (NPL) of 406 hazardous waste sites, including the Commencement Bay Nearshore/Tideflats area.

On April 13, 1983, U.S. EPA announced that an agreement was reached with the Washington Department of Ecology (WDOE) to conduct a remedial investigation of the hazardous substance contamination in the Nearshore/Tideflats Industrial areas of Commencement Bay. Under the Cooperative Agreement, the WDOE was delegated the lead role in the investigation.

1.2 SITE DESCRIPTION

Commencement Bay is an embayment of approximately 9 mi^2 in southern Puget Sound, Washington (Figures 1 and 2). The bay opens to Puget Sound in the northwest, with Tacoma situated on the south and southeast shores. The mean tidal range in Commencement Bay is 8.1 ft, with a diurnal range of 11.8 ft and an extreme range of 19 ft (COE 1983). Residential portions of the northeast Tacoma and the Browns Point section of Pierce County occupy the north shore of the bay. Ownership of the shoreline is vested in the Port of Tacoma, the city of Tacoma, Pierce County, the state of Washington, the Puyallup Indian Tribe, and numerous private parties. Much of the publicly owned land is leased to private industrial and commercial enterprises.

The Nearshore area is defined as the area along the Ruston Way shoreline from the head of City Waterway to Point Defiance, including all waters with depths less than 60 ft. The Tideflats area includes Hylebos Waterway, Blair Waterway, Sitcum Waterway, Milwaukee Waterway, St. Paul Waterway, Middle Waterway, City Waterway, and the Puyallup River upstream to the I-5 highway bridge (Figure 2). The boundaries for this project include

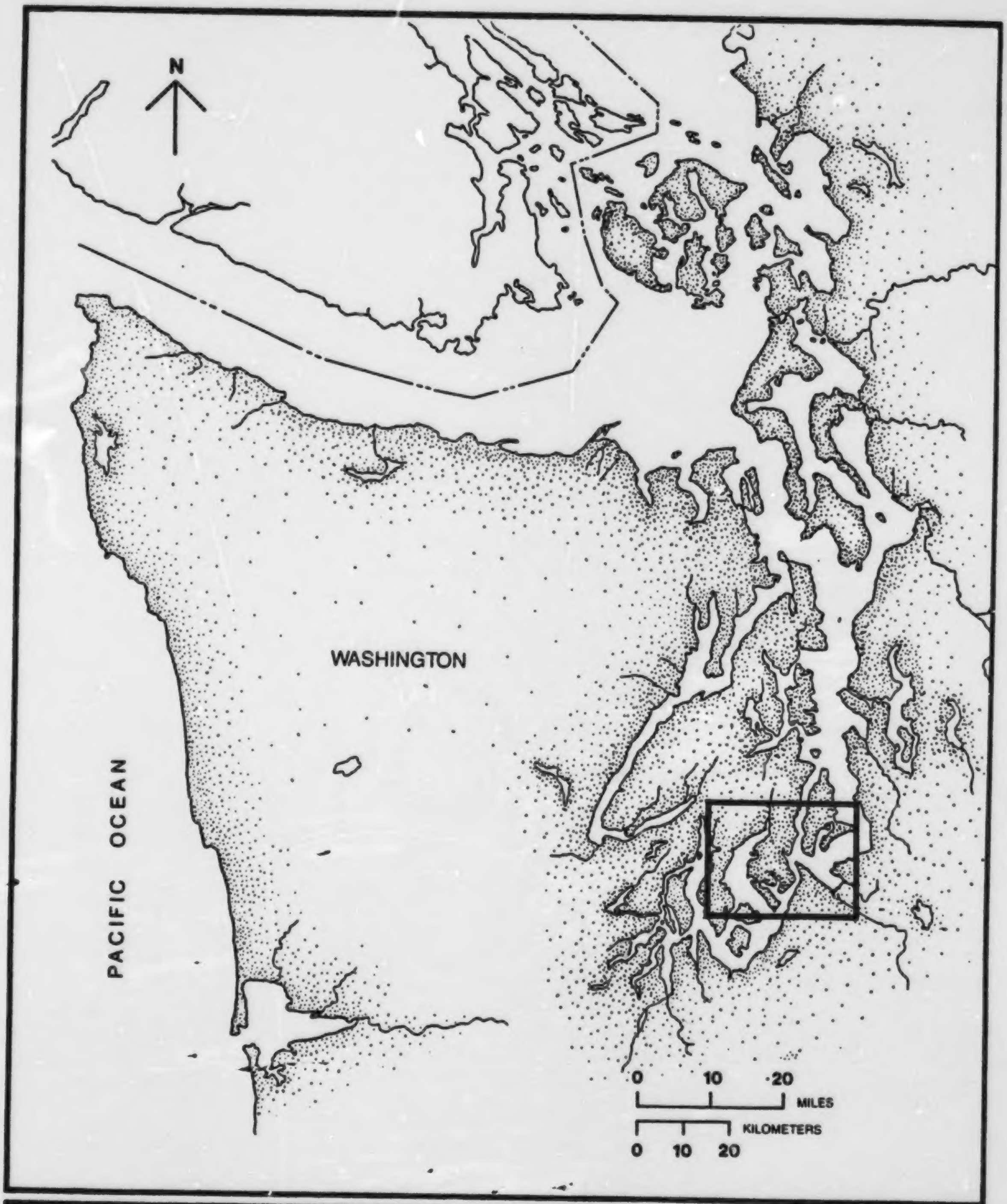

N
WASHINGTON
PACIFIC OCEAN
0 10 20 MILES
KILOMETERS
0 10 20

Figure 1a. General location of study area in Puget Sound.

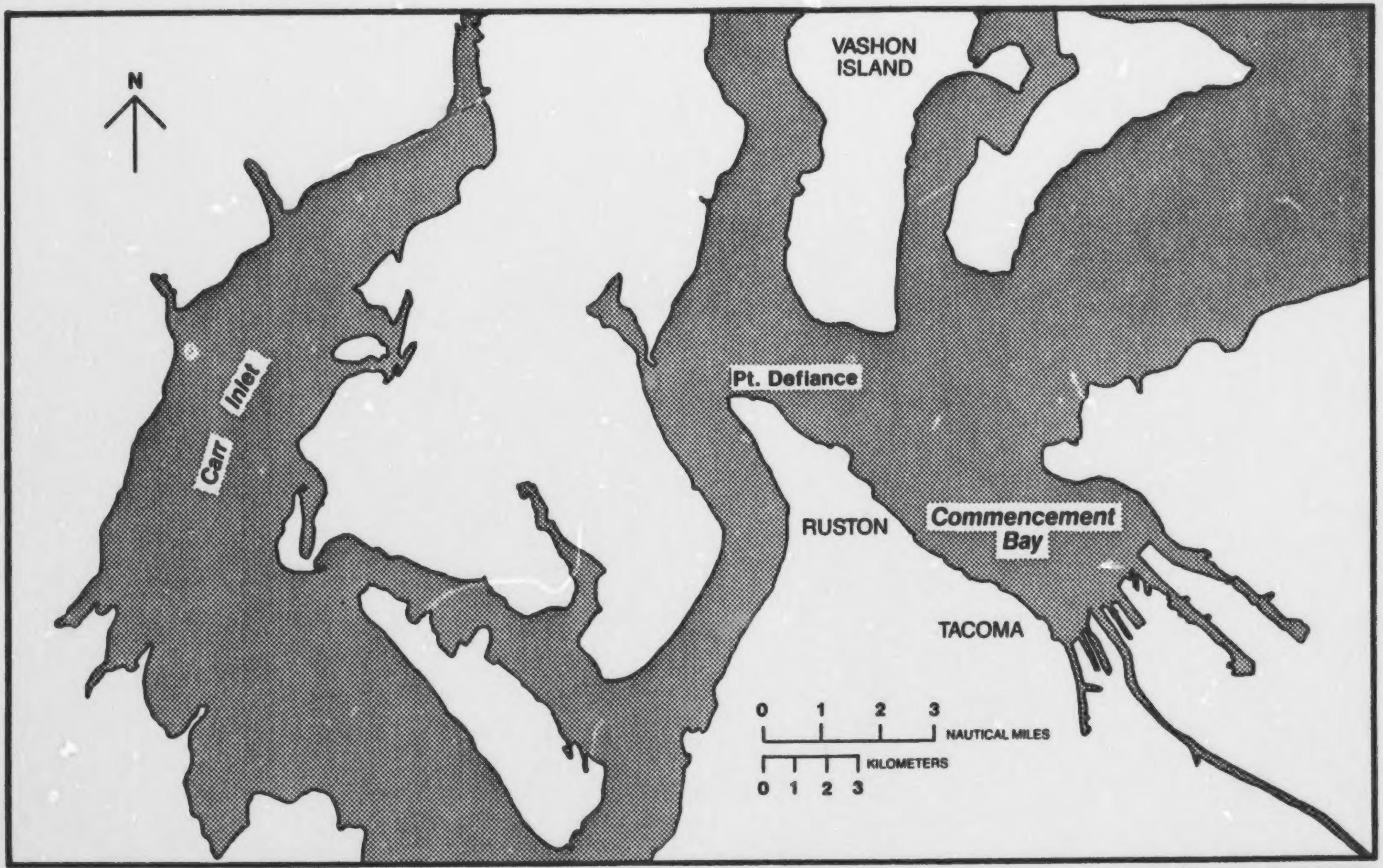

N
VASHON
ISLAND
Pt. Defiance
Carr
Inlet
RUSTON
Commencement
Bay
TACOMA
0 1 2 3
NAUTICAL MILES
KILOMETERS
0 1 2 3

Figure 1b. South and southcentral Puget Sound showing locations of Commencement Bay and Carr Inlet.

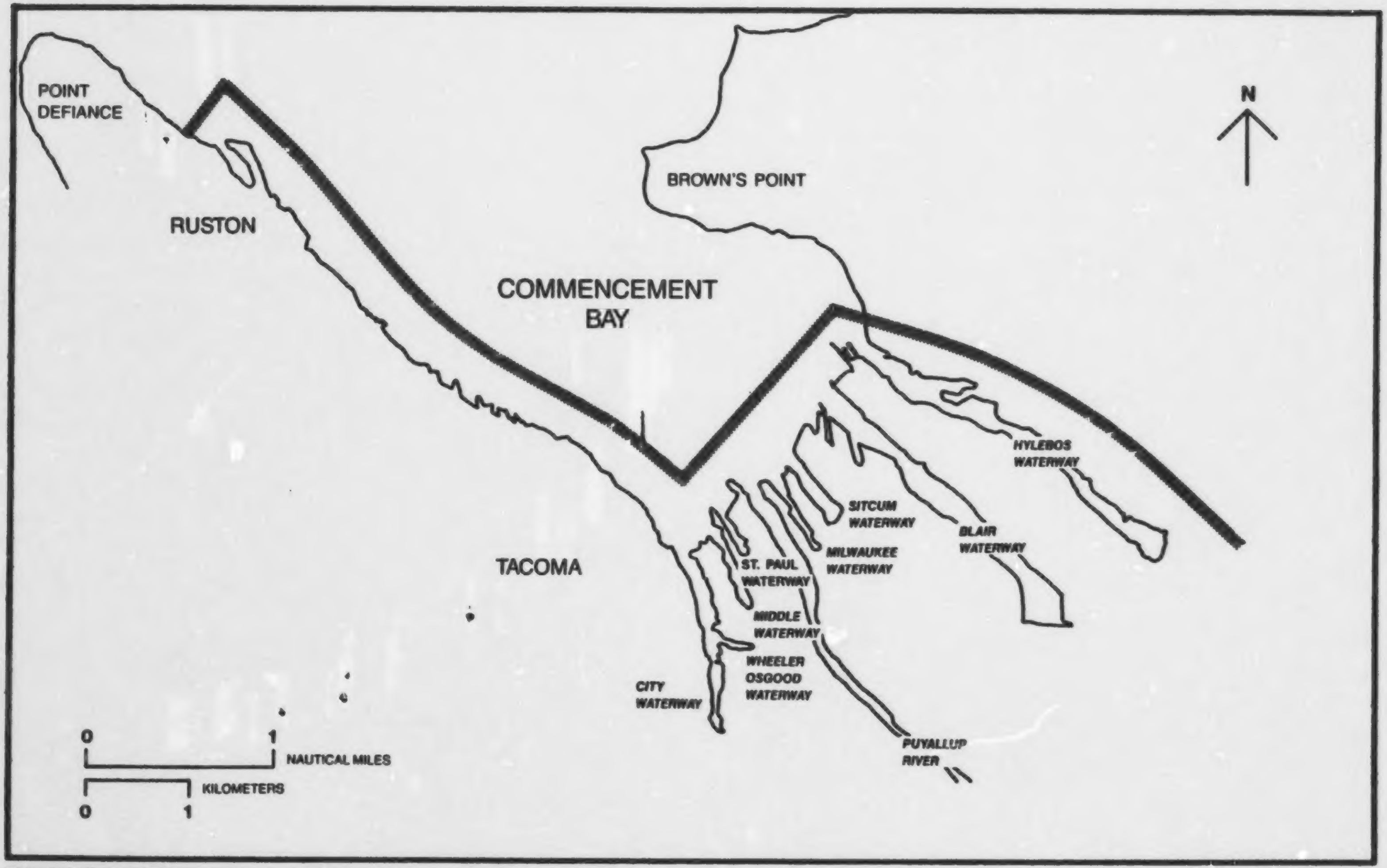

POINT DEFIANCE
RUSTON
BROWN'S POINT
COMMENCEMENT BAY
N
HYLEBOS WATERWAY
SITCUM WATERWAY
BLAIR WATERWAY
MILWAUKEE WATERWAY
ST. PAUL WATERWAY
MIDDLE WATERWAY
WHEELER OSGOOD WATERWAY
CITY WATERWAY
PUYALLUP RIVER
TACOMA
0
1
NAUTICAL MILES
KILOMETERS
0
1

Figure 2. Commencement Bay Nearshore/Tideflats study area.

the Nearshore and Tideflats areas and the associated terrestrial area with facilities that are possible sources of contaminants (also shown in Figures 1 and 2).

1.3 NATURE AND EXTENT OF PROBLEM

Urbanization and industrial development of the Commencement Bay area began in the late 1800s. At that time, the south end of the bay was primarily tideflats formed by the Puyallup River delta. Since their inception in the 1920s, dredge and fill activities have significantly altered the estuarine nature of the bay. Intertidal areas were covered and meandering streams and rivers were channelized. Numerous industrial and commercial operations located in the newly filled areas of the bay. These included pulp and lumber mills, shipbuilding, shipping, marinas, chlorine and chemical production, concrete production, aluminum smelting, oil refining, food processing, automotive repair services, railroad operations, and a number of other storage, transportation, and chemical manufacturing companies. The documented waste management practices of these operations included landfills, open dumps, chemical recycling and reclamation, and on-site storage and treatment facilities.

A smelter (ASARCO) has been located in the nearshore area by Ruston since the late 1800s. The plant, operational until March, 1985, generated substantial amounts of slag containing various metals. The slag was deposited along the shoreline near the plant and used as fill, rip rap, and ballast material in the Tideflats area. The slag material was also utilized to produce commercial sandblasting material used throughout the study area. While the hazards of the slag remain undetermined, it contains high concentrations of toxic metals, primarily arsenic.

Since initial industrialization of the Commencement Bay area, hazardous substances and waste materials have been released into the terrestrial, freshwater, groundwater, and marine environments. Discharges and dumping of solid and liquid, organic and inorganic waste materials, and contamination from airborne wastes entering via surface and groundwaters have modified the chemical quality of the waters and sediments in many portions of the area. These pollutants include metals (e.g., arsenic, lead, zinc, copper, mercury) and organic compounds [e.g., polychlorinated biphenyls (PCBs), dibenzofurans, chlorinated pesticides, pesticides (phthalates), and polynuclear aromatic hydrocarbons (PAH)].

Pollutant loadings in the Commencement Bay site originate from both point and nonpoint sources. Industrial surveys conducted by the Tacoma-Pierce County Health Department and the Port of Tacoma indicate that there are over 281 industrial activities in the Commencement Bay Nearshore/Tideflats area. Approximately 27 of these are NPDES-permitted discharges, including two sewage treatment plants. Nonpoint sources include two creeks; the Puyallup River; numerous storm drains, seeps, and open channels; groundwater seepage; atmospheric fallout; and spills. The Tacoma-Pierce County Health Department summarized point and nonpoint sources in 1983, identifying 334 drains (pipes), seeps, and open channels that empty into the Nearshore/Tideflats area (Rogers et al. 1983). Recent investigations by regulatory agencies have identified 429 additional point and nonpoint discharges in the study area. All known discharges were assigned an identifier, with location and description, and compiled in the project database (Tetra Tech 1985).

Previous investigations of the nearshore waters of Commencement Bay demonstrated the existence of sediment contamination by toxic pollutants, accumulation of some of these substances by biota, and possible pollution-associated abnormalities in indigenous biota (Crecelius et al. 1975; Riley et al. 1980, 1981; Malins et al. 1980, 1982; Gahler et al. 1982). These studies indicate that the highest concentrations of certain metals (arsenic, copper, lead, mercury) were found in sediments in the waterways, along the southwest shore, and near the ASARCO smelter. Sediment contamination by persistent organic compounds (e.g., PCBs) was detected in the heavily industrialized waterways and along the Ruston-Pt. Defiance Shoreline.

The toxicity of Commencement Bay sediments to infaunal amphipods was studied using acute bioassays (Swartz et al. 1982a). The waterways contain highly toxic and nontoxic sediments with heterogenous spatial distributions. Sediments with the highest toxicity were detected near docks, drains, and ditches, which are associated with pollutant sources. In the waterways, high toxicities were observed in intertidal sediments compared with those from midchannel and subtidal sites.

Commencement Bay, as part of the Puget Sound system, supports important fishery resources, especially anadromous salmonid populations. Although occupying Commencement Bay for only part of their life cycle, these species have critical estuarine migratory and rearing habitat requirements. The Commencement Bay area also supports recreational fisheries, including pollock, hake, rockfish, and cod. In addition, many of the other important fishes and invertebrates (e.g., English sole and crab) live in contact with the bottom sediments, resulting in a high potential for uptake of sediment-associated contaminants. Studies indicate that the incidence of liver lesions is greatest in fish from areas with high levels of sediment-associated contaminants (Malins et al. 1980). Higher prevalences of abnormalities have also been found in organs of shrimp and crabs from Commencement Bay waterways (Malins et al. 1980). Concern exists over the potential human health impacts from consumption of local seafood organisms that contain chemical contaminants. The Tacoma-Pierce County Health Department issued an advisory on fish consumption in 1982.

1.4 COOPERATIVE AGREEMENT

The general objective of the planned work under the U.S. EPA/WDOE Cooperative Agreement is to identify the worst problems and to provide a database and framework for future activities. The ultimate goal of the Superfund project is to remedy public health or environmental threats in a prioritized manner. The Remedial Investigation focuses on sediment contamination, effects on biota, and sources of contamination. The overall scope of the Remedial Investigation includes the following tasks:

Task 1. Investigative support
Task 2. Development of preliminary remedial objectives
Task 3. Determine type and extent of contamination and exposure pathways

Task 4. Determine sources of contamination and characterize as current or historical
Task 5. Endangerment assessment support
Task 6. Identify potential remedial technologies
Task 7. Safety plan, quality assurance/quality control plan.

The key questions to be answered during the Remedial Investigation include:

- Is the area contaminated?
- Does the contamination result in adverse effects?
- Is there a potential threat to public health?
- Can the contaminant sources be identified?
- What are the potential remedial action alternatives?
- Would remedial action reduce the threat to the environment or to public health?

In order to answer these questions, the following goals and objectives were set for the Remedial Investigation:

- Define a problem sediment
- Apply definition of problem sediment to delineate problem areas
- Determine problem chemicals for problem areas
- Determine problem sources for problem chemicals
- Prioritize problem areas, problem chemicals, and problem sources
- Assess impacts of fish and crab consumption on human health
- Document alternative methods of dredging, handling, and disposing of contaminated sediments
- Initiate a decision-making framework for managing the disposal of contaminated sediments
- Identify potential remedial alternatives

1.5 REPORT OVERVIEW

This report represents work completed under the U.S. EPA/WDOE Cooperative Agreement for Task 6: Identify Potential Remedial Technologies. It draws on the entire Commencement Bay Superfund Investigation, including assessments of chemical contamination, biological effects, toxicity, public health concerns, and source identification. Potential remedial technologies and actions for contaminated sediments and source control are presented in

Section 2. A description of the waterway segments considered to be problem areas, a discussion of contaminants of concern and their potential sources, and remedial actions that should be screened and evaluated during the Feasibility Study are included in Section 3.

2.0 REMEDIAL TECHNOLOGIES

2.1 INTRODUCTION

Remedial technologies that are potentially applicable to Commencement Bay are identified and discussed in this section. Available technologies are separated into six groups:

- Direct waste discharge control methods
- Surface water controls
- Groundwater controls
- Sediment removal methods
- In situ sediment treatment methods.

Remedial technologies in the first three categories address source control for the contaminants of concern, while the last three categories focus on the contaminated sediments. In general, only those technologies that are applicable to the problem areas in Commencement Bay will be discussed except emerging and new technologies (particularly in situ sediment treatment methods) for which there are many unknowns, and whose effectiveness and applicability have not been demonstrated. The following information is provided for each method:

- Brief description
- Advantages/disadvantages
- General availability
- Examples where the method has been considered or implemented.

Where possible, new and emerging technologies are included. In some instances, general cost information has been provided. Further information on these and other remedial technologies can be found in Handbook for Evaluating Remedial Action Technology Plans (U.S. EPA 1983) and Removal and Mitigation of Sediments Contaminated with Hazardous Substances (JRB Associates 1984).

2.2 DIRECT WASTE DISCHARGE CONTROLS

The most common mechanism by which contaminants enter Commencement Bay is through the direct discharge of wastewater effluents and solid wastes (e.g., metal ores, ore concentrates, slag, and sand blasting materials). There are approximately 27 facilities that are permitted to discharge process wastewaters and/or non-contact cooling water to the waterways of Commencement Bay. Typically, these dischargers are permitted for the more conventional parameters [i.e., biochemical oxygen demand (BOD), chemical oxygen demand

(COD), total suspended solids (TSS), pH, and residual chlorine]. However, industrial surveys often reveal the presence of additional contaminants that have more serious environmental impacts than the conventional contaminants. The Commencement Bay area has a very diverse industrial and commercial community, including metal platers, chemical manufacturers, petroleum refining and storage facilities, sand and gravel companies, food processing facilities, metals smelting industries, and port facilities. Technologies to reduce discharge of contaminants from a facility are specific to the particular industry and to the contaminant of concern. Source control technologies may vary among plants within an industry, depending on factors such as plant age, process lines, raw products, operation controls, reuse/recycle processes, and level of waste treatment or pretreatment at the plant. Control of contaminants from industrial and commercial sources involve detailed engineering studies evaluating process control and structural modifications and improvements. A different or higher grade raw product may be necessary to reduce the amounts of contaminants discharged through the outfall and/or stack. Implementation of one or more of these control measures may be necessary to achieve the desired contaminant levels in plant discharges. Typically, a particular discharge route was identified (e.g., process wastewaters, stack emissions), and where applicable, direct waste discharge control measures were recommended for a potential source. However, the specific in-plant source controls necessary for contaminant reduction were not designed. This type of detailed source control evaluation and design was not within the scope of this report. Instead, when source investigations implicate a particular commercial or industrial facility, control of the problem contaminants becomes the responsibility of that facility.

2.3 SURFACE WATER CONTROLS

Surface water controls are remedial actions to reduce water infiltration and to reduce or control runoff. These control measures also stabilize the surface of contaminated areas and reduce erosion. Surface control measures that may have application within the Commencement Bay Nearshore/Tideflats area include surface sealing/capping, grading, revegetation, and runoff diversion/collection. These are well-established techniques that will be considered as source control remedies for areas within the immediate Commencement Bay drainage area.

Costs to implement surface water controls will vary significantly with each site, depending on the specific technology and several site-specific factors (e.g., availability of materials and equipment, haul distances, volume of fill material, labor requirements, sampling and testing needs). A general methodology for estimating costs of surface water control remedies and the unit costs associated with those remedies is provided in *Handbook for Remedial Action at Waste Disposal Sites* (U.S. EPA 1982).

2.3.1 Surface Sealing/Capping

Surface sealing or capping is the process by which contaminated areas are covered to prevent surface water infiltration, to control erosion, or to isolate and contain contaminated materials (U.S. EPA 1982). Several impermeable cover materials and sealing techniques are available for these applications. Specific-site conditions and desired function will dictate the most suitable cover material and application method. Cover materials include clay and soil-clay mixtures, asphalt, synthetic liners, fly ash and soil-fly ash mixtures, concrete and soil-concrete mixtures, chemical sealant/stabilizers, and multilayered systems.

Although advantages and disadvantages of each technology varies with site-specific conditions, a few general characteristics are identified below.

Clay and soil-clay mixtures

- Well suited for cover materials in humid climates, but tend to shrink and crack in dry climates
- Not suitable for direct contact with organic or inorganic acids and bases
- Costs depend on availability.

Asphalt

- Not effective for containing some vapors
- Not suitable for exposure to excessive heat, may crack
- Not suitable for capping wastes with high concentrations of organic chemicals
- Relatively expensive.

Fly ash and soil-fly ash mixtures

- Relatively inexpensive or free
- May leach soluble trace pollutants that add to environmental contamination.

Concrete and soil-concrete mixtures

- Relatively expensive
- May require special mixing or spreading methods
- Not favorable in climates with significant freeze-thaw cycles or in areas with shrink-swell soils
- Not suitable when in contact with corrosive organic compounds and sulfurous waste products
- May have a design life up to 50 yr.

Chemical sealants/stabilizers

- Not favorable in climates with significant freeze-thaw cycles or in areas with shrink-swell soils
- Relatively expensive
- May require special mixing and spreading methods
- Not suitable when in contact with corrosive organic compounds and sulfurous waste products.

Multilayered systems

- Relatively expensive
- Combines general layers that serve an integrated function
- Individual applicability and constraints of each layer must be considered in the design.

2.3.2 Grading

Grading is generally used to describe reshaping the ground surface in order to manage surface water runoff, infiltration, and erosion (U.S. EPA 1982). In general, grading involves four steps: excavation, hauling, spreading, and compaction. The selection of a specific grading technique for a given site will depend on the desired function of that graded site. A graded surface may reduce or enhance infiltration, or detain or promote runoff. Equipment and cover (or fill) material needs will vary with the intended topographic modification to be made. Dozers and loaders are common grading equipment. Specialized equipment is also available. Grading is often performed in conjuction with surface sealing and revegetation of a contaminated area. This surface water control measure probably has little application in the highly commercialized/industrialized area in the immediate vicinity of Commencement Bay, because most of this area is paved. However, grading of landfills and waste sites within the drainage area of Commencement Bay may be appropriate.

2.3.3 Revegetation

Revegetation stabilizes a contaminated area by decreasing erosion and reducing runoff. Revegetation is usually a cost-effective method of site stabilization, especially when preceded by surface sealing and grading (U.S. EPA 1982). This remedy probably has little application in the highly commercialized/industrialized area in the immediate vicinity of Commencement Bay, since most of this land is paved. Revegetation may be an effective method for waste sites and landfills in the upland drainage areas. In addition to the soil stabilizing effect, the vegetation will also contribute to development of fertile soils and better site appearance. Selection of vegetation will depend on soil, climate, and waste characteristics. Grasses, legumes, trees, and shrubs are commonly used for revegetation.

2.3.4 Diversion and Collection Systems

The purpose of constructing diversion and collection systems is to provide hydrologic isolation of runoff and run-on. Surface runoff can be controlled to minimize additional leachate generation or erosion of cover materials (U.S. EPA 1982). Well-established construction techniques for diverting and collecting surface water include dikes and berms; ditches, trenches and diversions; terraces and benches; down pipes, chutes, and culverts; seepage basins; and sedimentation basins. Functional use and site-specific conditions will dictate the most appropriate technique.

Factors affecting the design of each diversion and collection system include flow, function (diversion or collection), site topography, design life (short-term or permanent), construction details, operation and maintenance requirements, availability of materials and equipment, site preparation requirements, and site configuration. Although advantages and disadvantages of each technology will vary between sites, some general characteristics are mentioned below.

Dikes and Berms: well-compacted earthen or pavement ridges or ledges immediately upslope from or around the perimeter of a facility or contaminated area.

- Not applicable for large amounts of runoff/run-on
- Provides short-term protection (i.e., $\leq$ 1 yr) against erosion and infiltration
- May require substantial amounts of fill material
- Not suitable for large areas (>5 ac) (U.S. EPA 1982)
- May require periodic inspection and maintenance
- Usually require some form of stabilization.

Ditches, Diversions, and Waterways: excavated drainageways used above and below contaminated areas to intercept and direct runoff.

- May be temporary or permanent
- Not suitable for slopes >15 percent
- May require paving or other form of stabilization.

Terraces and Benches: Relatively flat areas constructed along the contour of very long or very steep slopes to reduce runoff velocity and divert flow around contaminated areas. This control method has little applicability for the problem sources in Commencement Bay.

Downpipes, Chutes, and Culverts: usually temporary structures to convey surface waters within an enclosed conduit.

- Mitigates erosive damage since flow is not in contact with ground surface
- Prevents surface water from being in contact with contaminated soils
- Not suitable for large areas (>5 acres) (U.S. EPA 1982)
- May be constructed quickly during emergencies or severe storms
- Relatively inexpensive
- May overflow and cause excessive localized erosion if improperly designed
- Suitable for very steep slopes.

Levees: earthen embankments that function as flood protection structures for sites subject to riverine flooding or tidal flow.

- Not suitable for sites located directly within open floodways (U.S. EPA 1982)
- Usually constructed of compacted impervious fill material
- May be temporary or permanent
- May require periodic inspection and maintenance
- May require drains or periodic pumping
- Failure of structure may require emergency measures
- Cost effective if materials are available at the site.

Seepage Basins: impoundments to intercept runoff. This control method has little applicability for the problem sources in Commencement Bay.

Sedimentation Basins: impoundments to control suspended solids entrained in surface waters prior to discharging to receiving water.

- Usually implemented with some form of surface water diversion or flow channeling
- Detention time must be sufficient to allow particulate matter to settle
- Water treatment may be required if runoff is contaminated

- Solids accumulate in basin; periodic inspection and maintenance may be required
- Not suitable for removal of soluble organic and inorganic chemicals
- Performs poorly during periods of heavy rains (U.S. EPA 1982)
- May require inlet structure to prevent scouring and to dissipate energy
- Requires an erosion-free spillway to discharge surface water
- Special solids handling may be required if dredged materials are contaminated.

2.3.5 Stormwater Controls

Many contaminants enter Commencement Bay via stormwater runoff. Storm drains discharge to all the waterways and along the Ruston-Pt. Defiance Shoreline. The significance of storm drains as a source of contaminants varies from waterway to waterway. City Waterway has the greatest number of storm drains within the study area, including the two 96-in storm drains that serve south Tacoma (CS-237) and Nalley Valley (CN-237). These storm drains were determined to be the major source of several contaminants of concern in City Waterway. Sitcum Waterway also receives significant loadings of its contaminants of concern via storm drains. Conversely, Middle Waterway has few storm drains and little source data are available on them. Since elimination of stormwater runoff is not possible, remedial measures focus on the control of individual sources within the storm sewers' drainage areas. Possible sources include industrial and commercial connections, groundwater infiltration, and sanitary source cross connections. Typically, the relative portions of the total stormwater flow from runoff, unauthorized connections, groundwater infiltration, and sanitary sewer cross connections are unknown. Investigations of the storm sewer system are necessary to delineate the relative significance of these sources within the drainage areas. Identification of sources within stormwater drainage areas is recommended prior to development and evaluation of potential remedial alternatives.

If end-of-pipe remedial measures are considered (e.g., treatment) without implementation of source control within the drainage areas, then source investigations are not necessary. This remedial alternative is not prudent, and will not discourage additional discharges to the storm sewer system. General remedial technologies that may be applicable to reduce contamination reaching Commencement Bay stormwater collection systems include:

- An in-depth study of potential sources within the drainage areas (i.e., surveys, inspections, smoke testing) to determine unauthorized connections and locations of frequent discharges to the storm sewers

- Inspection of storm sewer lines for breaks, cracks, or poor pipe connections where contaminated groundwater may enter the collection system and to repair where necessary

- Sanitary sewer survey to locate and eliminate cross connections within the storm sewer systems

- Improvements in materials handling within the drainage area (focusing on commercial and industrial activities) to reduce contaminants reaching the storm drains through spillage of product and waste products

- Diversion or channelization of storm water out of Commencement Bay (to be used in conjunction with other treatment/disposal options)

- Construction of sedimentation ponds to settle particulate matter from storm water prior to discharge

- Treatment of storm water by physical or chemical means (i.e., filtration, carbon adsorption, flocculation/coagulation)

- Discharge to POTW (may not be permitted).

Typically, a surface water control plan will involve the implementation of two or more of the technologies listed above. Limitations and disadvantages of one technology may be redeemed with the integration of another. Combining technologies requires a specific plan to ensure that individual technologies complement one another and meet the remedial action goals.

2.4 GROUNDWATER CONTROLS

Groundwater controls applicable to Commencement Bay are those technologies that prevent the migration of contaminants into groundwater or remove contaminants already present in surface or groundwater reaching Commencement Bay. There are several applicable groundwater control technologies that may achieve this objective. Some technologies confine or contain the existing area of contaminated soils or buried suldges to prevent further migration. Other technologies operate by constructing barriers to contain the contaminated plume or to divert uncontaminated surface and groundwater from contaminated areas. Physical removal of groundwater is also a control technology. These are well-established technologies that will be considered as potential remedial groundwater controls for Commencement Bay.

Several incidences of groundwater contamination were confirmed and several others identified within the Commencement Bay vicinity. Groundwater contamination was confirmed in Hylebos and City Waterways. Groundwater may be contaminated in Sitcum Waterway and along the Ruston-Pt. Defiance Shoreline. Typically, contamination is associated with historical and ongoing industrial and commercial activities adjacent to the waterways and the Ruston-Pt. Defiance Shoreline. Groundwater contamination occurred from several waste disposal practices, including use of unlined waste lagoons; burial of wastes and sludges from industrial processes; spillage of raw product and waste materials; use of ASARCO slag as ballast, fill, and rip rap throughout the Commencement Bay area; leakage from old underground storage and distribution facilities; and leaching from landfills. Groundwater monitoring is recommended at sites where contamination is suspected. If contamination is confirmed, additional source investigations are necessary to characterize the aquifer prior to development of potential remedial alternatives. Four groups of groundwater control technologies are discussed, including surface sealing/capping, impermeable barriers, subsurface drains, and groundwater pumping. Costs to implement groundwater control technologies vary significantly with each source, depending on the specific technology and extent of the groundwater contamination. A general methodology for estimating costs of groundwater control remedies is provided in the Handbook for Remedial Action at Waste Disposal Sites (U.S. EPA 1982).

2.4.1 Surface Sealing/Capping

Surface sealing or capping of areas that contain contaminated materials reduces the potential for migration of contaminants into the groundwater by preventing the infiltration of surface water. Infiltrating surface water may transport contaminants by mobilizing them from soil, buried sludges, slag, and landfills into groundwater. Several surface sealing/capping materials were discussed in Section 2.3.1 of Surface Water Controls. These technologies are also effective in minimizing infiltration of surface water in contaminated areas. Paving is the most common surface sealing/capping method used in the Commencement Bay area.

Bottom sealing or the use of synthetic liners is often necessary to prevent leaching of contaminants from waste lagoons or ponds into underlying groundwater. Typically, industrial waste lagoons in the Commencement Bay Tideflats area were constructed without consideration of groundwater protection. Some of these waste lagoons were discontinued and contamination associated with them removed (e.g., Occidental Chemical Corporation). However, others continue to receive industrial waste without adequate liners or impermeable bottom surfaces (e.g., Kaiser Aluminum and Pennwalt Chemical Corporation).

2.4.2 Impermeable Barriers

Impermeable barriers are used to divert groundwater flow away from a contaminated area, or to contain groundwater emanating from a contaminated area. Placement of any type of impermeable barriers should be preceded by thorough hydrogeologic and geotechnical investigations to determine design factors (e.g., groundwater flow direction, depth to groundwater, depth to bedrock or impervious layer, hydraulic head, chemical characteristics of soil and groundwater). Impermeable barriers are an effective groundwater control for upper aquifers. Extreme efforts are required to place barriers at depths greater than 80 ft (JRB Associates 1984). Additionally, installation of impermeable barriers may increase the upgradient hydraulic head resulting in localized heightening of the water table. Therefore, consideration must be given to activities upgradient of impermeable barriers that are within the area influenced by higher groundwater table. Heightening of groundwater may increase leaching of contaminants if landfills or buried waste sites are located upgradient of the impermeable barrier.

Selection of a construction material for impermeable barriers depends on local groundwater and soil characteristics, type of contaminants, and overall cost-effectiveness. Impermeable barriers include slurry walls, grout curtains, and sheet piling cut-off walls.

2.4.3 Subsurface Drains

Subsurface drains may be constructed downgradient of a contaminated area to collect shallow groundwater and prevent further migration of contaminants. Typically these drains are not feasible for collecting groundwater at depths greater than 40 ft (JRB Associates 1984) because of construction difficulties. These drains have their greatest applicability at log sorting yards (if shallow groundwater is determined to be contaminated) and waste burial locations (if underlying groundwater is protected by an impermeable layer). Subsurface drains are generally more cost effective than other groundwater removal methods (e.g., pumping) if contamination is confined to the upper aquifer. Subsurface drains are often used in conjunction with flow diversion and/or water treatment technology. Impermeable barriers may be constructed upgradient of the contaminated area to reduce the amount of groundwater flow to the subsurface drains. Subsurface drains may be constructed with or without drain pipe. Design types of subsurface drains include French drains, conventional pipe drains, and dual media pipe drains.

2.4.4 Groundwater Pumping

Groundwater pumping is used to remove contaminated groundwater, to control the migration of contaminated groundwater, or to lower the water table. Evaluation of hydrogeologic characteristics is necessary prior to design and implementation of a control measure that utilizes groundwater pumping. Definition of the contaminant plume is necessary for placement of groundwater wells. Chemical characterization of the contamination is also necessary if removed groundwater requires treatment and/or disposal. Groundwater contamination was confirmed in deep aquifers adjacent to Commencement Bay. For these situations, groundwater pumping in conjunction with source control remedies to reduce future contaminant releases is probably the most feasible alternative for control of groundwater contamination. There are several groundwater pumping strategies, depending on the ultimate goal (e.g., removal for treatment or for control of contaminant plume). Groundwater pumping options include extraction wells, injection/extraction wells, and injection wells. Caution must be exercised to avoid saltwater intrusion into the groundwater when designing a groundwater pumping strategy in the Commencement Bay vicinity. The presence of brackish water may limit water treatment and/or disposal options for the contaminated groundwater.

2.5 SEDIMENT REMOVAL METHODS

Removal of problem sediments generally should be conducted only when the source of contamination is historical or the current source is controlled. The technology for sediment removal is centered around dredging. As part of the Commencement Bay Nearshore/Tideflats Remedial Investigation, the U.S. Army Corps of Engineers prepared a report entitled _Evaluation of Alternative Dredging Methods and Equipment, Disposal Methods and Sites, and Site Control and Treatment Practices for Contaminated Sediments_ (COE 1984).

In general, specific dredging methods are divided into two categories: mechanical dredging or hydraulic dredging. The remaining sections are devoted to briefly summarizing the findings of the U.S. Army Corps of Engineers report and integrating other pertinent literature.

2.5.1 Mechanical Dredging

Mechanical dredges remove materials through the direct application of mechanical force to dislodge and excavate bottom sediments. Types of mechanical dredges include clamshell, dragline, bucket ladder, dipper, bucket wheel, and other excavating equipment such as backhoes and loaders. Typically, these are vessel-mounted. However, they may be track-mounted or land-based if the appropriate site conditions exist. Mechanical dredges do not transport the material to the disposal site. Instead, materials are released into a nearby barge that transports it to the disposal site. Occasionally, dredged materials are released to a temporary, nearby, land-based storage area. The primary advantage of mechanical dredges is their ability to remove sediments at nearly in-situ densities. This maximizes the solids content and subsequently minimizes the scale of facilities required for transport, treatment, and disposal of dredged material. However, mechanical dredges have relatively low production rates compared to hydraulic dredges, ranging widely from 50 to 600 yd^3/h. These production rates vary significantly with the type of dredges, bucket size, mobility of the equipment, dredging technique and other site-specific conditions (e.g., available work area and distance to disposal point). The major disadvantage of mechanical dredges (as compared to hydraulic dredges) is the excessive amounts of sediments that are resuspended during operation of these units. Suspended solids are generated when bottom sediments are agitated during mechanical dredging operations. Generally, the two main turbidity control techniques are cofferdams and silt curtains.

Cofferdams are installed when hydraulic isolation of an area of contaminated sediment is desired. Typically, the use of cofferdams is limited to applications with shallow water depths (typically under 10 ft). For this reason, Wheeler-Osgood Waterway may be the only problem area where use of a cofferdam is feasible. This waterway is relatively inactive and much of it is intertidal. Conversely, most waterways in Commencement Bay are deep (greater than 25 ft), with active shipping traffic, and therefore use of cofferdams would not be feasible.

Mechanical dredging operations will require control of resuspended solids since the sediments are contaminated with hazardous materials. Silt curtains installed around the dredging site will trap suspended solids and debris generated by the dredging operation. Silt curtains are usually constructed of nylon-reinforced polyvinylchloride in 90-ft sections and joined together at the site to provide the desired length. Silt curtains are installed in several configurations depending on site-specific needs. Circular configurations would most likely be necessary in Commencement Bay because of the tidal influence that reverses the flow in the waterways.

2.5.1.1 Clamshell Dredges--

Clamshell dredges are crane-operated devices with a bucket attached to a cable and pulley mechanism at the end of a boom. Anchors and spuds are secured, then the open bucket is dropped from the dredge into the sediments. Material is dislodged and held in the bucket by closing the jaws. The bucket is then raised from the water and swung over the temporary storage area and released. As the bottom of the waterway is dredged to the desired depth to remove contaminated sediments, the anchors and spuds are released, the dredge is moved forward, and the process is repeated. Clamshell dredges are barge-mounted or track-mounted (land-based), depending on the accessibility of the site.

Clamshell buckets range in capacity from 1 to 18 yd^3 and have an effective working depth of approximately 100 ft. Clamshell dredges have limited production rates, typically 30 to 60 buckets/h (COE 1984), but have an inherently high degree of position and depth control. For these reasons, clamshell dredges are particularly effective for removal of contaminated sediments in confined areas (e.g., around docks and piers). They can effectively remove all but the most cohesive materials at in-situ densities.

The greatest disadvantage of the clamshell dredge is the excessive suspended solids generated from agitation of the sediments. Watertight clamshell buckets were developed by the Japanese and the U.S. Army Corps of Engineers to minimize the resuspension of solids in the water column. This type of bucket is sealed (tongue-in-groove) when the jaws close and the top of the bucket is covered to minimize the loss of dredged material as the bucket is pulled up through the water column. Studies performed by the U.S. Army Corps of Engineers comparing watertight and conventional clamshell buckets showed a 30-70 percent decrease in suspended solids generation throughout the water column with the watertight bucket (COE 1984). The studies also suggest that watertight buckets produce a higher level of resuspension near the waterway bottom. This may be attributed to the shock waves of water that precede the watertight bucket. Conventional clamshell buckets can be converted to watertight buckets with minor structural modifications (COE 1984).

In general, it is recommended that clamshell dredges, if used to remove contaminated sediments, have large buckets to minimize the resuspension of solids during dredging operations. Large clamshell dredges are a well-established technology and are readily available in Puget Sound and the Pacific Northwest.

2.5.1.2 Dragline Dredges--

Dragline dredges are crane-operated devices with a drag bucket connected by a cable to the boom. The boom is extended and the bucket is thrust into the sediments. The bucket is then filled by pulling it towards the crane through the material to be removed. Dragline dredges are barge-mounted or land-based, depending on the location of the dredging site. Generally, a dragline dredge offers a longer reach than a clamshell dredge operated by the same crane. However, control of the dragline is inferior to that of the clamshell. A variety of bucket sizes and boom lengths are available, depending on the type of material to be removed and the depth of sediment to be excavated. The maximum digging depth of a dragline is approximately equal to half the length of the boom, while the reach is slightly greater than the length of the boom (U.S. EPA 1982). Production rates are somewhat limited with dragline dredges, and resuspension of solids due to agitation of the sediments and bucket leakage tends to be considerable. In general, the medium and larger buckets tend to be more efficient and generate less suspended solids. Availability of dragline dredges is good in the Pacific Northwest.

2.5.1.3 Bucket Ladder Dredges--

A bucket ladder dredge consists of a submersible ladder supporting a continuous chain of buckets that rotates around two structurally held tumblers. As the buckets rotate around the bottom of the ladder, they scoop up the material to be removed and transport it to the top of the ladder, where it is discharged into a storage area on the dredge. Bucket ladder excavation has its most common application in mining, quarry, and sand and gravel operations. Although production rates for these types of dredges are generally higher than for other mechanical dredges, they tend to have higher capital costs and produce excessive suspended solids during operation. Resuspension of solids results from mechanical agitation of the sediments and leakage of dredged materials from the buckets. For these reasons, bucket ladder dredges are not recommended for dredging of contaminated sediments unless the dredging area is within a dewatered portion of a waterway (e.g., Wheeler-Osgood). Development of watertight buckets is being considered by dredging manufacturers to reduce the suspended solids generated by this type of dredge during transport through the water column. However, this improvement would not mitigate suspended solids generated by agitation of the sediments.

2.5.1.4 Dipper Dredges--

Dipper dredges are similar to backhoes and have their most effective application when excavating materials of soft rock and dense sedimentary deposits (e.g., clay or glacial till). A bucket attached to a long boom is forcibly thrust into the sediments to be removed. Sediments are dislodged by the violent mechanical action, generating considerable turbidity due to agitation of sediments. Production rates for dipper dredges are comparable to those of other types of mechanical dredges. Dipper dredges tend to produce higher levels of suspended solids in the water column and are more expensive to use than other mechanical dredges (COE 1984). Dipper dredges are not considered a very effective method of removing contaminated sediments due to the additional suspended solids control measures necessary and the potential for dissolved contaminants to migrate from the site. Dipper dredges probably have little applicability for the Commencement Bay problem areas.

2.5.1.5 Bucketwheel Dredges--

The underwater bucketwheel was developed for application in marine mining and dredging based on decades of experience with "dry" bucket wheel excavators. Thorough testing of prototypes have proven that they can be used successfully for these applications (Hahlbrock 1983). Bucketwheels are used worldwide for deep-sea mining projects. The bucketwheel has characteristics of both mechanical and hydraulic dredges. A bucketwheel dredge head mechanically dislodges the sediments and a submerged pump conveys the dredged material from the bucketwheel to the discharge point via a suction line. Dredged material is discharged to hoppers on the dredge vessel, discharged to barges tethered to the dredge vessel, or transported through floating or submerged pipelines to the disposal area. Material is dislodged when buckets are pushed into the sediments and then lifted, filled with sediments, as the bucket wheel rotates through the excavation. Bucketwheel dredges are large vessels with very high production rates, averaging approximately 2,100 yd^3/h (range 845-3,965 yd^3/h). Production is dependent primarily on sediment type, which will dictate the type of bucketwheel, cutting method (i.e., vertical or horizontal cut), and anchoring arrangement. Dredging depths up to 330 ft are possible with floating carrier bucketwheel systems. In general, bucketwheels can effectively dredge sediment types ranging from moderately hard rock to adhesive soils (Hahlbrock 1983). However, different sediment types will demand specifically designed wheels.

Bucketwheels are classified as suction or transport, depending on the location of the hydraulic transport system. The suction chamber on a suction bucketwheel is located just behind the cutting buckets in the lower wheel area. This design allows immediate transport of loosened material and probably minimizes the resuspension of sediments. The transport bucketwheel is similar to the bucketwheels used on land in that the suction chamber is located at the highest point of the wheel. Transport systems were determined to achieve higher production rates than suction systems under all simulated operating cases. This is explained by the fact that entry into the suction chamber is aided by the force of gravity, despite the buoyancy of the soil underwater (Hahlbrock 1983). Although turbidity production was not discussed for these simulations, resuspension of sediments is probably significant due to mechanical agitation of the sediments. Additional data concerning the levels of turbidity generated by bucketwheels must be obtained before their applicability to removal of contaminated sediments can be determined. Feasibility of this technology for Commencement Bay also depends on the availability of the equipment and production costs (cost/yd^3). Based on a review of literature and related case studies, it appears that bucketwheels have not been used in the Pacific Northwest.

2.5.1.6 Backhoes and Loaders--

Backhoes (power shovels) and front-end loaders (bucket loaders and tractor shovels) have limited application in the removal of sediments contaminated with hazardous materials. Backhoes are barge-mounted or operated from land. However, their lateral reach is quite limited and their vertical reach restricted to the boom length. Backhoes normally used for subsurface excavation are capable of reaching 40 ft or more below the level of the machine. Additionally, backhoes can operate in shallow water up to several feet to provide access for larger or barge-mounted dredging equipment.

Loaders are used to excavate loose or soft materials in a limited vertical range of a few feet above and below grade. Since loaders must be operated within close proximity to the material being removed, barge-mounted and land-based equipment are not usually practical. Loaders may be practical in shallow water, if material to be removed is sufficiently loose or soft. Loaders may also be useful for removing sediments from dewatered portions of a waterway (e.g., potentially, Wheeler-Osgood).

In general, the production rates of backhoes and loaders are comparable to those of other mechanical dredges. However, suspended solids in the water column generated from the mechanical agitation of sediments is considerable with these types of dredges. Backhoes and loaders are more practical to excavate and load dredged materials from a temporary storage area or dewatered site, and therefore have little applicability for the problem areas of Commencement Bay.

2.5.2 Hydraulic Dredging

Hydraulic dredges are usually barge-mounted systems that employ diesel- or electric-powered centrifugal pumps to remove and transport sediments in a liquid slurry form. Pumps are barge-mounted or submersible, depending on the hydraulic dredge. Sediment slurries are pumped into bins or hoppers on the dredges, into barges tethered along the side of the dredge, or pumped long distances (up to 2 mi) through floating or pontoon-supported discharge lines (pipelines) to a disposal/treatment site (COE 1984). For transport distances exceeding 2 mi, booster pumps may be required. Other conditions may also necessitate the use of booster pumps (e.g., coarse sediments, small dredges, and transport to disposal areas). Sediments are removed by suction. In all but the most unconsolidated materials, suction must be preceded by some mechanical device to dislodge the sediments. A suction head is mounted on an adjustable ladder to facilitate depth control during the dredging operation. Classification of hydraulic dredges is generally by size according to the diameter of the discharge line: small dredges have 4-in to 14-in diameter discharge lines, medium dredges have 16-in to 22-in diameter discharge lines, and large dredges have 24-in to 36-in diameter discharge lines. Hydraulic dredges include plain suction, cutterhead, dustpan, hopper, and several portable and specialized models. Hydraulic dredges may either be self-propelled or require towing between dredging sites.

Overall, hydraulic dredging methods generate less turbidity than mechanical methods, due to the minimal mechanical agitation of the bottom sediments and the transport of dredged material through the water column within an enclosed pipeline. The level of turbidity produced varies significantly with the type of hydraulic dredge, operational controls, and sediment characteristics. Specialized head adaptations are available to reduce resuspension of solids. Improved operational controls can be implemented to further reduce the resuspension. Unlike mechanical dredges, hydraulic dredges cannot remove large objects and debris (e.g., drums and scrap metal) from waterways.

The major disadvantage of conventional hydraulic dredges is the relatively large discharge flow rates resulting from the dilution of sediments. Slurries from hydraulic dredging operations are typically 10 to 20 percent solids by wet weight. These low solids concentrations are necessary for transport via the centrifugal pumps. Large storage and treatment facilities are required for the excess volume of material resulting from the low solids concentrations. Lined surface impoundments and/or dewatering areas may be desirable to reduce the water content prior to treatment and disposal of dredged materials. Water removed from the dredged sediments may require treatment, depending on physical and chemical characteristics of the sediment contaminants (e.g., their solubility in water). To mitigate this disadvantage, technology design has emphasized hydraulic systems to remove sediments at high solids concentrations. There are many specialized dredges on the market, in various stages of development, that pump high solids and/or produce low turbidity. Specialized dredges include portable dredges (i.e., Mud Cat, Mini Dredge, Dragon) and specialized head adaptations (i.e., DREX, Cleanup, Refresher, and Waterless).

2.5.2.1 Suction Dredges--

The plain suction dredge is the simplest type of hydraulic dredge, relying entirely on the suction created by the centrifugal pump to dislodge and transport the sediments. Sediments and dilution water are vacuumed off the waterway bottom through the suction head and the slurry is discharged to a stern-mounted pipeline leading to the disposal point. By adding devices to dislodge sediments, the suction dredge can be converted to other types of hydraulic dredges (e.g., cutterhead, dustpan, Cleanup). The suction head is mounted at the end of an adjustable ladder. Depth and position of the suction head are controlled by cables attached to the ladder. Plain suction dredges are most effective in the removal of free-flowing materials such as sands, gravels, and unconsolidated sediments. Since no mechanical device is attached to the suction head, hard cohesive materials such as clay and firm native bottom sediments are not readily removed by this method. Plain suction also minimizes turbidity generated by mechanical agitation of the sediments. Slurries of 10 to 15 percent solids by weight can be achieved in appropriate applications (Hand et al. 1978).

2.5.2.2 Cutterhead Dredges--

The cutterhead dredge is a modification of the plain suction dredge. The cutterhead has spiral blades shaped in the form of a basket. The cutterhead is attached to the end of the suction pipeline, which is mounted on an adjustable ladder to facilitate depth control of the dredge head. As the cutterhead rotates, sediments are dislodged allowing transport through the suction line. A secondary purpose of the cutterhead is to screen out debris that may enter and plug the suction line. There are many types of cutterheads and modifications to cutters to allow dredging in different types of materials. Cutter diameters range from 2 to 10 ft. Production rates for cutterhead dredges are governed principally by the pipeline diameter and the dredge pump capacity. Production rates range from approximately 71 yd^3/h for a small dredge (6 in) up to 3,600 yd^3/h for a large dredge (30 in) (COE 1984). In general, dredging depth and cut depth increase with dredge size. The maximum dredging depth for a conventional large cutterhead is 50 ft below water level. For dredging depths in excess of 50 ft, modification of the dredge ladder is required (COE 1984). The maximum cut depth for a large cutterhead is 36 in. Large set and very thick cuts should be avoided since they will bury the cutterhead. This may create excessive suspended solids if the suction cannot remove all of the material that was dislodged (COE 1984).

A properly designed cutterhead will dislodge the bottom sediments and guide them towards the suction efficiently. However, some resuspension of solids is generated from mechanical agitation of the bottom sediments. The level of resuspension from cutterhead operations is a function of the quantity of material dislodged but not removed by the suction head. Field studies indicate that levels of resuspended solids are highly variable, depending primarily on operational controls. Technology development has emphasized cutterhead designs that reduce resuspension of solids. This is especially important in dredging contaminated sediments. The cutterhead dredge is the most widely used dredge in the United States and in the Pacific Northwest (COE 1984). Their widespread use and availability make them among the least expensive dredging methods. Initial mobilization and set-up costs are considerable because conventional cutterheads are not self-propelled and must therefore be transported between dredging locations by towboats. These units are economically feasible only when quantities to be dredged are sufficient to amortize the initial costs to obtain a competitive average cost per cubic yard.

2.5.2.3 Dustpan Dredges--

The dustpan dredge is a modification of the suction dredge. The dustpan has a widely flared dredging head upon which several high-pressure water jets are mounted. The water jets dislodge the bottom sediments, which are then removed by suction through the dustpan head as the dredge is moved ahead into the excavation. Like the suction and cutterhead dredges, this unit is not self-propelled and must be moved along by winches or a towboat.

The dustpan is most effective in removal of free-flowing granular sediments. This dredge was developed by the U.S. Army Corps of Engineers to maintain navigation channels in uncontrolled rivers such as the Mississippi River (COE 1984). Typically, slurries of 10 to 20 percent solids by wet weight are achieved with this type of dredge. The dustpan dredge is not recommended for use in waterways with fine-grained sediments because pressure from the water jets creates excessive turbidity. However, the dredge may be operated with low or no water pressure to minimize turbidity. Clogging of the suction line may result if the dustpan is used to dredge sediments with a high clay content (COE 1984). Most dustpan dredges have low discharge pressures and are not well suited or designed to transport slurries distances over 1,000 ft without the assistance of a booster pump (COE 1984). The major advantage with dustpan dredges is that they are able to excavate very deep cuts, up to 6 ft in a single pass (COE 1984), which may help to expedite projects. All dustpan dredges are classified as "large," with discharge line diameters of 30 in or greater. Due to the specific design purpose of the dustpan dredge, there are several limitations to its application.

2.5.2.4 Hopper Dredges--

Hopper dredges are large, self-propelled, seagoing ships with sediment containers called hoppers. These may be designed with barge-type hulls or molded hulls similar to ocean vessels (COE 1984). Unlike most hydraulic dredges, sediments are pumped and contained on board these vessels rather than discharged to a barge or transported through a pipeline. Hopper dredges also differ from other hydraulic dredges in that these vessels move ahead of the excavation, dragging the dredged heads, rather than pushing them into the excavation, as is typically the procedure. Suction created by centrifugal pumps located on the dredge removes sediments from the channel bottom and raises them through the draglines. Dredged materials are then discharged into the hoppers.

Since hopper dredge heads are capable of removing only a few inches of sediment, successive passes over the same area may be necessary to achieve the desired dredging depth. Normally, as the hopper is filled, overflow water is discharged at the dredge site allowing solids to settle and concentrate. This is usually not acceptable when removing contaminated sediments. When the economical load is achieved, the hopper is considered to be full. The economical load is specified as the maximum overflow pumping time that allows the greatest amount of solids accumulation in the hopper considering pumping and non-pumping times (travel to and from the disposal site) of the dredging cycle and the volume of solids that are hauled to the disposal site (no overflow loss) (COE 1984). When dredging contaminated sediments, hoppers are considered full at the point of overflow (assuming no overflow is permitted). Therefore, it is unlikely that an economic load will be achieved for these conditions. Typical slurries of 20 percent solids are produced with no overflow as compared with an average of 70 percent solids in an economic load. This drastically impacts the economical feasibility of this method due to the additional trips to the disposal site and increased volume of material to be treated and or disposed. Hopper dredges have often proven to be the most economical type of dredge when the disposal sites are not within economical transport distances using pump and pipeline systems. These two methods may become more comparable when handling contaminated sediments, which necessitates less productive operation of hopper dredges.

Hopper dredges are generally classified into sizes according to hopper capacities: large class hoppers have capacities of 6,000 yd^3 or greater, medium class hoppers have capacities of 2,000 to 6,000 yd^3, and small hoppers have capacities of 500 to <2,000 yd^3 (COE 1984). The pumping rates range from 15 to 150 yd^3 per minute (3,030 to 30,300 gal/min). Hopper dredges have a maximum dredging depth of approximately 60 ft, and a minimum dredging depth of approximately 10 ft depending on the fully loaded draft depth. Hopper dredges are most effective for dredging deep, rough-water shipping channels and they are one of the few dredges capable of dredging waterways that are sloped or vary in elevation. Hopper dredges have good maneuverability, but cannot dredge sediments from around piers, docks, and other structures. Availability of small and medium hopper dredges is good in the Pacific Northwest. They can be mobilized and initiate dredging in relatively short periods of time (COE 1984).

Suspended solids generated from a hopper dredge are largely the result of overflow from the hopper bins. For operations involving contaminated sediments, suspended solids are expected to be minimal since overflow is usually not permitted.

2.5.2.5 Specialized Design Dredges--

Variations of conventional hydraulic dredges have developed during the last few years in Japan, Europe, and the United States. Several needs have led to these variations, including special applications, improved performance, mitigation of negative environmental impacts, and economic advantages. Among these specialized designs are portable dredges and special head adaptations. Some models, such as the Mud Cat, have the characteristics of being portable and utilizing a special head adaption.

The availability of a specialized design dredge varies primarily on whether it is a foreign or domestic technology. If a specialized design is not marketed domestically, its use may require a specific international, government, or private agreement (COE 1984). Production may be restricted to a small number of units due to the limited application of some designs. Availability of these specialized designs is likely to be unfavorable if the demand exceeds the current supply. Additionally, new and emerging designs may be limited to a few test models. These factors influence the availability of a special design and dictate the initial and mobilization costs. Technologies with limited availability should not be rejected on the basis of initial costs alone, since the overall economic feasibility is determined by analysis of all costs, including operation and maintenance of all equipment; transportation, treatment and disposal of dredged material; labor; and other project-related expenses. Specialized design dredges may prove to be economically competitive with conventional methods once the initial costs are amortized.

2.5.2.5.1 Portable Dredges--The U.S. Army Corps of Engineers defines "portable" dredges as those that can be transported intact over existing roads or that are constructed in a modular fashion for easy dismantling and transportation (Clark 1983). Weight and capacity are excluded from the definition because these factors are said to be too arbitrary. Dredges are not considered portable if they must be transported via water, either by barges or under their own power.

Characteristics of portable dredges vary significantly, and have a wide range of capacities and design features. Dredging depths vary from 3 ft for smaller, one-piece units to over 60 ft for larger, modular-built dredges (Clark 1983). Production rates vary from 20 to 1,800 yd^3/h. Portable dredges are available with a variety of cutters: bucketwheel, ladder with chain cutter, twin vertical cutters, dustpan, and cutterhead with jet pump (Clark 1983). The U.S. Army Corps of Engineers Waterways Experiment Station performed a comprehensive survey of portable dredges available in the United States, as presented in Survey of Portable Hydraulic Dredges (Clark 1983). This document provides design information on 48 individual models (12 separate manufacturers), including main dredge pump data, cutter assembly, working capacity (digging depth, production rates, and pumping distances), and general physical characteristics of the model. Also provided in the survey is a rating of "portability" and equipment requirements for transport and launching of each dredge.

Portable dredges have their greatest application in shallow or isolated waterways. Their characteristically low draft depths (under 2 to 6 ft) enable them to dredge sediments in shallow waters. Maneuverability is excellent with their relatively small size, which enables them to operate efficiently in isolated or congested waterways. Individual models will not be discussed in this report. A brief description of the Mud Cat line of dredges is presented herein. The reader is referred to Clark (1983) for specific design details of other models.

- Mud Cat Dredges - A line of portable hydraulic dredges manufactured by a separate division of National Car Rental Systems Inc. (Clark 1983). The Mud Cat is the most widely known and used portable dredge and is available in several models. Dredging depths range from 10 to 25 ft and production rates range from 60 to 200 cubic yards per hour. The Mud Cat (SP-810) is equipped with a centrifugal pump mounted directly behind the 8-ft horizontal auger. The pump and entire cutterhead can be buried in the sediments to facilitate high solids/low dilution pumping (U.S. EPA 1982). The Mud Cat has a retractable mud shield surrounding the cutter equipment for greater suction efficiency and minimal sediment resuspension. Low turbidity production of the Mud Cat makes this technology particularly applicable for removal of contaminated sediments. Mud Cat dredges are available in the Pacific Northwest and their portability allows for easy transport via truck or air (COE 1984). Due to limited dredging depths, use of Mud Cats in Commencement Bay is restricted to intertidal areas or during low tides.

2.5.2.5.2 Special Head Adaptations--The primary focus on development of special head adaptations is the design of systems that remove sediments at high solids concentrations and/or minimize the resuspension of sediments. These systems typically have low production rates, although when dredging contaminated sediments, this feature is usually of secondary importance to reducing turbidity and/or achieving high solids concentration. Since many of these special head adaptions are relatively new, there may be many unknowns concerning their applications and limitations. Additional research, development, and experience may be necessary to fully define their usage. Among the most noteworthy special head adaptations discussed herein are the DREX, the Cleanup, the Refresher System, and the Waterless.

- DREX Head - The DREX head was developed by the Japanese company Mitsubishi Heavy Industries Ltd. Unlike most hydraulic dredges with a fixed head on an adjustable ladder, the DREX head allows the suction mouth to move laterally with respect to the dredge head and ladder. Once the ladder swings through an arc removing sediments, the suction mouth can be moved prior to returning to the ladder. This allows dredging in parallel arcs rather than intersecting arcs as is the procedure for conventional cutterheads. Parallel arcs are a more efficient tracking pattern since there is essentially no deadheading in the dredging operation. For this reason, use of the DREX head increases solids content of sediment slurries because pumping of excess water as the dredge head passes over previously dredged areas has been eliminated. Use of the DREX head will reduce the total volume of slurry to be treated and/or disposed, but it does not appear to have any significant advantage over other conventional hydraulic methods in minimizing the resuspension of sediments.

- Cleanup System - The Cleanup system, developed by the Japanese company Toa Harbor Works, is a unique method for dredging highly contaminated sediments. Design emphasis for the Cleanup system was maximum control of turbidity, with secondary importance on maximizing the solids content of the slurry. The Cleanup head consists of a shielded auger mounted on a ladder at the front end of a pipeline dredge. As the ladder moves through the excavation, the shield guides the sediments towards the suction of a submerged centrifugal pump (COE 1984). Resuspension of solids is minimized by shielding the auger with a wing that adjusts vertically, enabling the head to maintain contact with the surface sediments and preventing the sediments outside the head from being influenced by the turbulence within the head. The dredging operation is monitored by sonar devices that indicate elevation and by underwater televisions that observe effectiveness of the turbidity controls. The Cleanup system has proven effective at removing contaminated sediments with minimal resuspension of solids and with high solids concentrations. Suspended solids concentrations around the Cleanup system ranged from 1.7 to 3.3 mg/L at the sediment surface to 1.1 to 7.0 mg/L at 10 ft above the suction equipment, relative to background near-surface levels of less than 40 mg/L (COE 1984). These levels of suspended solids are approximately one-fiftieth of those associated with conventional hydraulic dredging methods. Since the Cleanup system is a Japanese-manufactured system, its availability in the United States may be limited. Domestic marketing is likely in the near future due to the system's compatability with existing American-made equipment (COE 1984). Limited availability of the Cleanup system is likely to result in higher mobilization and initial costs for this method.

- Refresher System - The Refresher system is a modification of the cutterhead recently developed by the Japanese. The Refresher uses a helical-shaped gather head to feed the sediments into the suction. It is equipped with a curve to reduce resuspension of sediments. The dredge ladder, articulated to keep the head level with the waterway bottom, facilitates dredging over a wide range of depths. Results of comparison tests in similar material show the Refresher system generates one-fifteenth of the total resuspended solids generated by the operation of a conventional cutterhead (COE 1984). Since the refresher is a Japanese-manufactured system, its availability in the United States may be limited. Domestic marketing is likely in the near future due to the system's compatability with existing American-made equipment (COE 1984). Limited availability of the Refresher system is likely to result in higher mobilization and initial costs for this method.

- Waterless Dredge - The Waterless dredge was developed by the American firm, Waterless Dredge Company, for the removal of sludges from lagoons with minimal water content. The dredge head is equipped with a shrouded "roll-over" cutter and a submerged centrifugal pump. As the cutterhead is moved through the excavation, sediments displace the water in the cutterhead and block entry of water into the dredge pump inlet. At the limit of the cut in one direction, the cutterhead rolls over 180 degrees so that the face of the cutterhead is open to receive sediments in the return direction. The Waterless dredge continues to be field-tested and its application in removal of contaminated sediments has been limited. It is reported that the Waterless dredge can pump slurries containing less than 10 percent water by volume with little resuspension of sediments.

2.6 IN SITU SEDIMENT TREATMENT METHODS

In situ treatment methods eliminate the need to remove contaminated sediments, thereby reducing the impacts associated with dredging. These methods include:

- Cover/capping
- Sealants and grouts
- Sorbents and gels
- Ground freezing
- Chemical and biological treatment.

However, other than cover/capping sediments, few of these methods have been utilized to control contaminated sediments. Sealants and grouts have been used to stabilize sediments for offshore structures, but the remaining technologies are relatively new in terms of applicability to seafloor sediments. Specific methods are largely untested, and often depend on foreign-made equipment, which is in limited supply. The primary sources for the following discussion of these in situ treatment methods are A Feasibility Study of Response Techniques for Discharges of Harzardous Chemicals that Sink (Hand et al. 1978) and Removal and Mitigation of Sediments Contaminated with Hazardous Substances (JRB Associates 1984).

2.6.1 Cover/Capping

Covering or capping contaminated sediments has been used to minimize water column and biota exposure to the contaminants. This technique is useful as 1) a temporary measure to minimize the spread of contaminants until a long-term remedial measure is implemented; 2) a primary remedial measure to reduce impacts from contaminated sediments; and 3) a post-removal measure to cover any residual contamination. Many of the systems for applying cover materials were developed for dredging or open water dredged material disposal.

There are three overall groups of cover materials: inert materials, active materials, and synthetic liner materials. Inert materials include sand, silt, and clay and may be fine-grained, coarse-grained, or uncontaminated dredged spoils. Active cover materials include limestone, greensand, oyster shells, alum, alumina, ferric sulfate, and gypsum. The function of an active cover material as opposed to an inert material is to react with the contaminant to neutralize or detoxify it. Specific active cover materials should be selected on the basis of the contamination present. Neutralizing acids can be accomplished with limestone, oyster shells, or greensand. Bases can be neutralized with ferric sulfate or alum. Gypsum or ferric sulfate can be used for metal precipitation, while alumina is useful for fluoride removal. Active cover materials can be applied alone or with inert materials. However, care must be taken during placement of active cover materials because they can harm biota outside the contaminated area.

Synthetic liners are available in a variety of materials. Liners must be selected on the basis of their compatibility with the contaminated sediments and their ability to withstand temperature and seawater effects. Synthetic liners such as butyl rubber and chlorinated polyethylene are not compatible with oils and hydrocarbon solvents.

The effectiveness of different cover/capping materials depends on a number of factors. The principle determinants for inert and active covering materials are 1) turbidity and dispersion generated during application of the material; 2) impacts on benthic organisms; 3) scouring and resuspension of cover material once in place; and 4) resistance to leaching of contaminants. Turbidity and dispersion are a function of the delivery system used to place the cover material on the bottom. Impacts on biota are also directly related to the method of material delivery, the areal extent covered, and the toxicity of the material (particularly for active cover materials). The ability of the cover material to be recolonized without contaminant bioaccumulation depends on the type of cover material, its resemblance to natural sediments, the thickness of the cap (it must be thick enough to keep burrowing organisms from reaching the contaminated sediments), and the potential for contamination leaching through the cover.

The susceptibility to scouring and resuspension of cover materials is related to the particle size and shape, slope of the bottom, angle of repose of the cover material, degree of material cohesiveness, and the flow dynamics. The leaching of contaminated sediments through the cover material is governed by the permeability of the cover, which is directly related to grain size. The larger the grain size, the greater the potential for contaminant leaching. The amount of time before the contaminant would actually begin leaching from the area depends on the degree of sorption of contaminants by the cover material and the thickness of the cap.

Besides these controlling influences on the effectiveness of cover, active cover materials must also remain in place long enough to react with and treat the contaminated sediments. Gypsum and limestone tend to form a cement-like cover that resists erosion. Ferric sulfate, alumina, and alum are fine-grained and susceptible to erosion, while oyster shells and greensand are the most susceptible to scour. Inert cover materials can be mixed with the active materials to add erosion resistance, although effective interaction with sediments may decrease due to the reduced contact between the active cover material and sediments.

The effectiveness of synthetic liners is based on proper placement, adequate bonding of adjacent strips of liner, durability of the synthetic material, and provisons for venting gases that build up under the cover. The material must be placed on relatively flat areas that are free of jagged outcroppings and obstructions to prevent tearing. The liners need to be weighted (preferably with natural sediments) to prevent displacement and minimize tearing. This will also aid recolonization of the area. Adjacent strips of liner must be bonded well to provide a continuous cover for the contaminated sediments.

Several methods are available for delivering cover materials to the sea bottom. A barge-mounted roller apparatus has been proposed for laying synthetic liners at depths of 25-30 ft, but has not been tested. For inert and active cover materials, delivery can be accomplished by point-dumping, pump-down, submerged diffuser, or spray/spreader systems. Point-dumping involves barges or other vessels that release the cover materials from the water surface, allowing them to settle over the contaminated sediments. Such vessels have been extensively used for ocean disposal of dredged spoils deposited in protected coastal waters. The major drawback of this system is the high turbidity and possible dispersion as the material moves down through the water column. Also, silts and clays with low moisture content tend to fall in a clump, causing resuspension of contaminated sediments when they impact the bottom. Although sand is less cohesive and has a higher moisture content, a significant amount of turbidity and resuspension occurs.

Pump-down systems involve a barge loaded with the cover material and a telescoping tremie tube or similar means of conveying the material directly to the sea bottom. Since the material does not pass through the entire water column, turbidity and dispersion are not as significant a problem as with point dumping. Resuspension of contaminated sediments is also lessened as long as the discharge pipe is maintained close to the bottom. Pump-down systems are slower at covering a given area than are point-dumping systems and may require monitoring to ensure complete coverage of the contaminated sediments.

A submerged diffuser system can also be used to convey the cover material directly to the bottom and is very effective at controlling the material placement. The diffuser head reduces the velocity and turbulence during the material discharge, thereby reducing scour and turbidity. Thickness of the cover and impact velocity of the material can be controlled by varying the discharge velocity and height above the bottom. Sediments at depths of 100 ft can be covered with a submerged diffuser head.

Another system being tested is a spray or spreader system, which is similar to the pump-down system. A slurry with 15-20 percent solids of the desired cover material is pumped through a spreader pipe. The spreader pipe is not necessarily kept near the sediment surface, but the use of a slurry helps reduce turbidity.

Covering contaminated sediments has been considered or implemented at a number of sites. At the Kepone contamination site in the James River, covering some contaminated areas with an impervious blanket was considered but later rejected in favor of several dredging options. For the Mill River site with high lead concentrations in sediments, isolating the contamination with a clay or synthetic cap was evaluated as a remedial alternative. It was concluded that both short- and long-term environmental impacts would be moderate from the resuspension of sediment during the capping operation and later from erosion of the cap, with possible release of the contaminated sediments. Because of the river flow, there was also concern about anchoring a synthetic cap. Dredging was identified as the preferred alternative, despite estimated costs doubling those of the capping alternative. An impermeable liner was considered for PCB-contaminated sediments in the upper Hudson River, but was eliminated during initial screening because capping had not been demonstrated as feasible for rivers. Capping and covering were considered for the PCB contamination in Waukegan Harbor. An impermeable membrane seal was rejected because it was still in the conceptual stage and would have had a limited lifetime. Use of a clay cap was evaluated in combination with dredged material containment. A cofferdam would be constructed to contain contaminated sediments dredged from the upper harbor. After dewatering, the containment area would be capped with 3 ft of clay and 5 ft of fill. While not an in situ cap, this option was among those recommended for the site.

Capping was selected and implemented to control Stamford Harbor sediments contaminated with metals that were dredged from the harbor and disposed of in the Central Long Island Sound Disposal Area. Capping the material reduced impacts on the water column and benthic fauna. Two materials comparing the effectiveness and durability of sand versus silt caps were used to cap two disposal areas. Point dumping was used to deliver both cover materials. The silt material did not spread too extensively beyond the contaminated dredge spoils because of its cohesiveness. The sand material was less cohesive and tended to flow upon impact with the bottom. Both capping operations were judged successful, and subsequent efforts focused on evaluating the stability of the caps. Recolonization proceeded faster on the silt cap. A survey 5 mo after completing the covering operation indicated that over 2 m of the silt cap was lost, although no contaminated sediments were exposed. Hurricane storm waves and the roughness of the silt cap may have been responsible for the eroded cap. The nearby sand cap showed no evidence of material loss. It was concluded that capping operations with silt should include smoothing the final cap surface to improve erosion resistance. While more long-term monitoring is required, the operation involving the Stamford Harbor sediments demonstrates that capping is a viable alternative. Covering 34,000 yd^3 of contaminated sediments with 39,200 yd^3 of sand cost about $140,000.

2.6.2 Sealants and Grouts

Sealants and grouts are used extensively in offshore construction to stabilize sediments. These same techniques can be used to stabilize or cover contaminated sediments. The mechanism involved requires injecting or covering the sediments with a grout or sealant and allowing it to harden in place.

Sealants and grouts are divided into two types: chemical or particulate. Chemical grouts, such as urethane and acrylamide, have not been fully researched and data on their potential toxicity to benthic organisms are conflicting. Particulate grouts are more common, including cement, quicklime, silicates, and bentonite. The effectiveness of sealants and grouts depends on their particle size, viscosity, durability, and chemical compatibility. For chemical grouts, the lower the viscosity, the finer the grain size penetrated. For particulate grouts, the grain size of the grout regulates its penetration of the sediments. The permeability of the grout will determine its effectiveness to stabilize the sediments and keep water out. Chemical compatibility varies between different grouts and sealants. Quicklime is best suited for stabilizing sediments with inorganic contaminants. Clay and cement are not effective with acidic or basic sediments. The compatibility of bentonite must be evaluated on a case-by-case basis, while little is known for silicate grouts. Additives are available to enhance the hardening time, strength, and durability of grouts and sealants.

Several methods have been developed for grouting and sealing sediment, including hydraulic isolation followed by grouting, in situ covering and sealing, and in situ injection. In shallow waters (e.g., Wheeler-Osgood Waterway), cofferdams can be used to divert water and allow direct access to contaminated sediments. This simplifies the application of grouts and sealants, minimizes dispersion of the sediments, and the migration of contaminants. Grouts and sealants can be used directly on the sediments or after some contaminated sediments have been removed by dredging. Two approaches can be taken once the water has been diverted: a surface seal can be created or the grout can be mixed in with the sediments to stabilize them. For a surface seal, the material is pumped pneumatically to form a layer over the sediments of any desired thickness. Various types of vehicles have been designed to travel over the sediment surface and mix grouts into the sediments using rotor or trenching equipment. The depth of mixing is adjustable. The Japanese have utilized this approach and mixed lime or cement-based grouts to depths of over 6 ft. The mixing machines are also used to compact the sediments. With the cofferdam still in place, the sediment bottom is restored with clean sediment to achieve natural grades and enhance biological recovery.

Covering and sealing the sediments without diverting the water is more difficult, but several approaches have been developed. A telescoping tremie tube can be used to convey concrete from a hopper on a barge or platform directly to the sediment surface. The lower end of the tube is kept buried in the fresh sealant to force it to flow into position. If the sealant is simply allowed to rush out, it may segregate (losing its sealant properties) or disperse in the water column. Multiple tremie tubes are used to cover large areas, since trying to move a single tremie tube progressively over a large area greatly increases the chance of breaking the seal and dispersing material through the water column.

A concrete pump can also be used to place sealants on the sediment surface. Mobile units with variable-length arms are used economically to cover small or large areas. The U.S. Army Corps of Engineers has proposed using a modified diffuser head to lay the grout down on the sediment surface. Ideally this would be done in even-sized bands to provide an unbroken cover. To further enhance the success of the sealant cover, coarse aggregate can be placed on the sediment surface and the grout can be forced into the voids in the aggregate.

Another method involves injecting grouts or sealants into the sediments to stabilize them. This was used widely prior to construction of port and harbor structures. Some approaches use a number of injection pipes combined with mixing pipes to place the cement or lime-based slurry at the required depth and mix it into the sediments. The Japanese have developed systems allowing in situ stabilization of sediments down to depths of 25 to 40 m below the sediment surface. Continuous injection/mixing devices are also available to eliminate the need to raise, relocate, and lower the individual injection and mixing pipes. A cement slurry is continuously fed down to a mixing device that moves up and down within the sediments as it slowly moves through the area. The major disadvantage is the potential for causing resuspension of contaminated sediments before the grout can act. The need for stirring can be eliminated with a pressure injection system. As the pipe is slowly withdrawn from deep in the sediments, the grout is forced out by a high-speed jet. This has been used for landfills and was recently tested at a Superfund site in California.

Much of the information and equipment for grouting sediments is proprietary and not readily available. However, as previously indicated, this technology was successfully applied to sediments in a number of cases, although generally not for stabilizing contaminated sediments. Sealants and grouts were considered during the initial screening of remedial alternatives for the Upper Hudson River in conjunction with dredging and containment measures. It was determined that such a combination of technologies offerred no advantage over dredging alone. Sealants were used during the cleanup of mercury contamination in the North Fork of the Holston River. The river flow was diverted, the sediments were excavated down to bedrock, and the bedrock was sealed with concrete. Over 7,000 yd^3 of sediment was removed from the 1,000-ft stretch of the river. The exposed river bed was then covered with a 3-in layer of pneumatically applied concrete to prevent further contact between any residual contaminants and the river water.

2.6.3 Sorbents and Gels

The technology associated with sorbents and gels has been applied largely to spills of materials on land and surface waters. There has been little implementation of this technology to contaminated sediments. The mechanism involves placing the sorbent or gel in contact with the contaminant, allowing it to adsorb or bond with the contaminant, and then recovering the sorbent or coagulated sediment.

There are many types of sorbents, including activated carbon, polymer foams and fibers, and resins. Adsorption efficiency varies with characteristics of the sorbent material (e.g., porosity, surface characteristics-acidic, basic, hydrophilic, hydrophobic), properties of the contaminant (e.g., molecular size, solubility, polarity, solution pH), and contact time. Sorbents are more effective at removing contaminants from the water column over the sediments rather than from the sediments themselves. Activated carbon adsorbs a wide range of organic and inorganic materials, but is most effective with nonsoluble compounds. Polymer foams and fibers are generally made of polyurethane, polypropylene, or polyethylene. These materials have a much greater porosity than that of activated carbon. Resins made with a spongy, reticulated surface have a molecular porosity larger than that of activated carbon, but smaller than that of polyurethane foam. Resins are more versatile than polyurethane foam, but less versatile than activated carbon. If sulfonated, resins absorb metals and ionic organic compounds better than activated carbon. However, resins have a high cost and are limited in availability.

Gelling agents have been developed primarily for application to oil spills. They immobilize the oil in a mousse that is easily removed. The Japanese developed the Silica Bonding method for gelling contaminated sediments in order to minimize dispersion during dredging. The gel is a silicic coagulant composed primarily of sodium-silicate. The "hydrogel" formed when the gel is mixed with sediments decreases mobility and cohesiveness of highly hydrous sediments and becomes plastic with a weak bearing power. The "hydrogel" also obtains compressibility which prevents diffusion of sediments and minimizes oozing and leakage during dredging. Such gelling agents can be costly and have limited availability.

The use and effectiveness of sorbents and gels in actual situations are unknown. Activated carbon as a sorbent was identified as a potential remedial alternative during the feasibility study of PCB contaminated sediments in the upper Hudson River, but was dropped from further consideration during initial screening because it was an unproven in situ technology. Greater consideration was given to sorbents during the feasibility study of Kepone-contaminated sediments in the James River. Retrievable sorbents, polymer fibers, and activated carbon were investigated as "promising nonconventional treatment alternatives." Laboratory studies were initiated and activated carbon was found to be effective in retarding the availability of Kepone, but did not remove it from the sediments. The effectiveness of polymer films was questioned and they were considered for application only in embayments. Specific sorbents capable of removing Kepone were tested, but are not commercially available. In addition, for all of these sorbents, concern was raised over serious environmental impacts. Due to the complex assortment of contaminants found in each problem area, more than one type of sorbent or gel may be necessary to maximize contaminant removal. Even if the appropriate sorbents and gels were available, it is unlikely that this would be a cost-effective technology. In general, sorbents and gels are probably not feasible for the problem areas in Commencement Bay.

2.6.4 Ground Freezing

Ground freezing has been used in dam and tunnel construction to increase the structural supportiveness of soil and to eliminate water movement. The technique could be used to contain contaminated sediments or stabilize them for easier removal. Refrigeration probes are placed in a closely laid pattern in the sediment until the water in the sediment freezes. The ice crystals coalesce to form a block of frozen sediment. The frozen sediment is then lifted out with little disruption or dispersion of sediments. The sediment may also be kept frozen until a different technology, such as dredging or capping, is applied.

Although ground freezing methods are undergoing research, it is a costly procedure due to large energy requirements. Also, the method is best suited to small areas, since each probe affects an area only 1.5 ft in diameter. Ground freezing might be used to collect representative sediment samples. At this time, it appears to have little practicality for treatment or stabilization of contaminated sediments in the problem areas of Commencement Bay.

2.6.5 Chemical and Biological Treatment

Chemical and biological treatment have been used extensively for hazardous wastes in soil and groundwater, and the principles are potentially applicable to contaminated sediments. The advantage of these methods is that sediments may remain in place once they have been successfully treated. Chemical and biological treatment methods are summarized in Table 1, including most appropriate waste types, reagents, potential problems, and general comments. Precipitation (chemical binding), chemical dechlorination, and biological treatment are in situ treatment methods that may have some feasibility for the problem areas of Commencement Bay. A specific method for each problem area should be selected on the basis of contaminants present in the sediments. The major drawback of chemical treatment methods is that the reagents or their by-products may be toxic. Biological treatment requires that the sediments are aerated sufficiently to allow aerobic degradation. The effectiveness of each method depends on the extent of contact between the treatment reagents or microorganisms and the sediment. These methods are most effective when hydraulic isolation is achieved and the treatment can be applied directly to the sediments. Hydraulic isolation also makes it easier to mix treatment reagents or microorganisms into the sediments and thereby helps to ensure maximum contact with the contaminants. Various vehicles have been designed to deliver and mix materials for sediments protected by a cofferdam. Without hydraulic isolation, biological and chemical treatment would have limited success unless there is a way to keep the reagents or microorganisms in contact with the sediments. Otherwise the reagents may disperse, causing additional sediment contamination. Injection or subsurface mixing devices are required for mixing when hydraulic isolation is not possible. This can easily cause dispersion of sediments or reagents.

Chemical and biological treatment methods have been considered for several areas around the country. During initial screening of remedial technologies for the PCB contamination in the upper Hudson River, ultraviolet ozonation and chemical treatment were considered but rejected because they are unproven technologies. However, dechlorination was fully evaluated for remanent sediments exposed when the river level dropped and for dredged material. Dechlorination involving reaction of potassium hydroxide and polyethylene glycols with the PCB contamination has not been attempted in the field. Reagents would need to be rototilled into the exposed sediments and several applications might be necessary. This procedure would be limited in situ even with hydraulic isolation because of the possible length of time required before PCB levels were adequately reduced. Dosage rates, application methods, contact times, and the effects of sediment water content still need to be researched.

For the PCB contamination in Waukegan Harbor, 70 technologies were considered during the initial screening of potential remedies. None passed initial screening. Chemical oxidation and radiation were considered to be too early in the conceptual stage. Ultraviolet/ozonolysis was determined to be in a pilot stage suited for a closed system only and unable to penetrate

TABLE 1. SUMMARY OF IN SITU CHEMICAL AND BIOLOGICAL TREATMENT METHODS

Treatment Method	Waste Types Amenable	Treatment Reagents	Potential Problems	Comments
Neutralization	Acids & bases	• Weak acids and bases • To neutralize acids: calcium carbonate, sodium carbon or sodium bicarbonate; limestone or greenstone may be applied as active cover material	• Toxicity to pH-sensitive benthos if not, properly placed on the spill • Use of ferric sulfate under aerobic conditions may result in the formation of hydrous iron oxides which can scavenge heavy metals from water and may coat the gills of bottom feeders	• Containment of the spill or contaminated sediments, is required before neutralization in-situ • Remote pH, meter should be used to locate pH imbalances • Materials can be applied in-situ as solids either by broadcast spreading or use of hand shovels within the contained area • Materials can be applied in-situ as slurries using such methods as sand spreader, open pipe discharge or the diffuser head • Materials can also be applied by diverting stream flow and then spreading and mixing the neutralizing agents; limited to streams with relatively low flow velocity
Precipitation	Inorganic cations and anions	• Sulfide precipitation is most promising since metal sulfides are the least soluble metal compounds likely to form over a broad pH range. Calcium sulfate, iron sulfate, or gypsum may be used	• Potential for release of H_2S gas; likelihood increases as the reactivity of sulfide and metals decrease • Effective only under reduced conditions, oxidation to more soluble sulfide species could occur under aerobic conditions	• Containment of the spill or contaminated sediments is required in order to allow adequate time for reaction to proceed to completion • Solutions or slurries could be applied together with capping material (e.g., sand or clay) using methods such as pump down, open pipe discharge or the diffuser head • Solutions and slurries can be applied directly in calm waters using pumps and hoses • Mixing will generally be required so that formation of the precipitant will not prevent further reaction • Materials can also be applied by diverting stream flow and then spreading and mixing precipitating agents; reduced conditions should be maintained
Oxidation	Wide range of organics; highly chlorinated compounds and nitro aromatics are not well suited	• Oxygen and/or ozone, and hydrogen peroxide	• Oxidation can result in more mobile degradation products • Both ozone and hydrogen peroxide may react with organics in the water column or sediments which are not target compounds, thereby reducing effectiveness • Compounds which are sorbed to sediments may be difficult to oxidize	• Containment of spills or contaminated sediments is required prior to oxidation in order to prevent loss of oxidant and oxidation of non-target compounds outside the contaminated area

TABLE 1. (Continued)

Treatment Method	Waste Types Amenable	Treatment Reagents	Potential Problems	Comments
Oxidation (continued)			• Ozone will decompose back to oxygen rapidly in the presence of organics; stability of hydrogen peroxide is not well known	
Chemical dechlorination (KOHPEG process)	Highly chlorinated organics (e.g. PCB, dioxins)	Polythylene glycol and potassium hydroxide	• Treatment system can tolerate some water but limits have not been established • Degradation is temperature dependent and may proceed slowly at ambient temperatures	• Due to a limited tolerance of water, stream diversion and/or dewatering would be required prior to treatment
Biological treatment	Most organics are amenable to biodegration to some degree; groups which tend to be most refractory to aerobic decomposition include chlorinated and nitro organics, and PAH's with three or more rings; however, removal of nitro and chlorine groups may occur under reduced conditions	Microorganisms, oxygen source (for aerobic degradation) and nutrients	• Organics sorbed to sediments may be refractory • Degradation rates proceed very slowly at low temperatures • Partial degradation products may be more soluble or more toxic • Microorganisms used for treatment may be pathogenic	• Containment is required to confine microorganisms to contaminated areas when treating in-situ • Acclimated, mutant and genetically engineered microorganisms have or are being developed for degradation of a broad range of waste types • Considerable research is needed to find suitable means of maintaining adequate oxygen supply; research needs to concentrate on oxygen delivery systems as well as on the use of ozone and hydrogen peroxide an oxygen source

Source: JRB 1984

deeply into contaminated sediments. Biodegradation had progressed only to the laboratory stage and was unavailable for field use. These same limitations and disadvantages may apply when in situ biological and chemical sediment treatment methods are evaluated for the problem areas in Commencement Bay. A lack of laboratory and case study data confirming their feasibility as contaminated sediment management techniques may limit the consideration of in situ biological and chemical treatment methods.

3.0 PROBLEM AREAS AND POTENTIALLY APPLICABLE REMEDIAL TECHNOLOGIES

3.1 INTRODUCTION

The Commencement Bay Nearshore/Tideflats Superfund site encompasses a relatively large area composed of several individual waterways and is contaminated with a wide variety of substances. Due to the complex nature of this site, a method was developed to delineate the problem areas and to identify specific contaminants associated with the observed biological effects. The waterways of Commencement Bay and the Ruston-Pt. Defiance Shoreline were divided into segments based on apparent trends in sediment contamination (Figure 3). Problem areas within each segment were defined on the basis of sediment chemistry, toxicity, and biological data. Problem chemicals within each problem area were prioritized on the basis of their correlation with observed biological effects. Priority 1 chemicals were present at concentrations greater than an Apparent Effect Threshold (AET) and their distributions corresponded with gradients of observed toxicity or benthic effects. Priority 2 chemicals were also present at concentrations greater than an AET at more than one stations in a problem area, but either showed no particular relationship with gradients of observed toxicity or benthic effects, or insufficient data were available to evaluate their correspondence with gradients. Priority 3 chemicals were present at concentrations greater than an AET value at only a single station in a problem area. Problem areas were ranked using three criteria: environmental significance, spatial extent, and confidence in source identification. Each problem area was scored according to these criteria, as shown in Table 2. The final ranking was based on the total score. The problem areas with the highest scores were assigned highest priority for evaluation of remedial action. Locations of problem areas and their priorities for remedial action are shown in Figure 4.

Subsections of this chapter are arranged in descending order of priority for remedial action. Discussion of each problem area includes a general physical description of the appropriate waterway; definition of the problem area, including the extent of contamination and the types of contaminants; summary of contaminant sources; potential remedial technologies; and identification of specific data needs.

In general, remedial technologies evaluated in this report are classified as source control measures or contaminated sediment management. Potential source control measures were recommended based on the mechanisms by which contaminants reach the waterway. In all cases, where a source was identified, technologies for control of the direct waste discharge were warranted. In all problem areas, surface water controls were appropriate for stormwater runoff discharging either directly or indirectly into Commencement Bay. Many source control technologies take the form of improved operation recommended to prevent or minimize release of contaminants into the environment. These recommendations are specific to each source, but not to each individual plant process. Evaluation of in-plant process control technologies was not within the scope of this report.

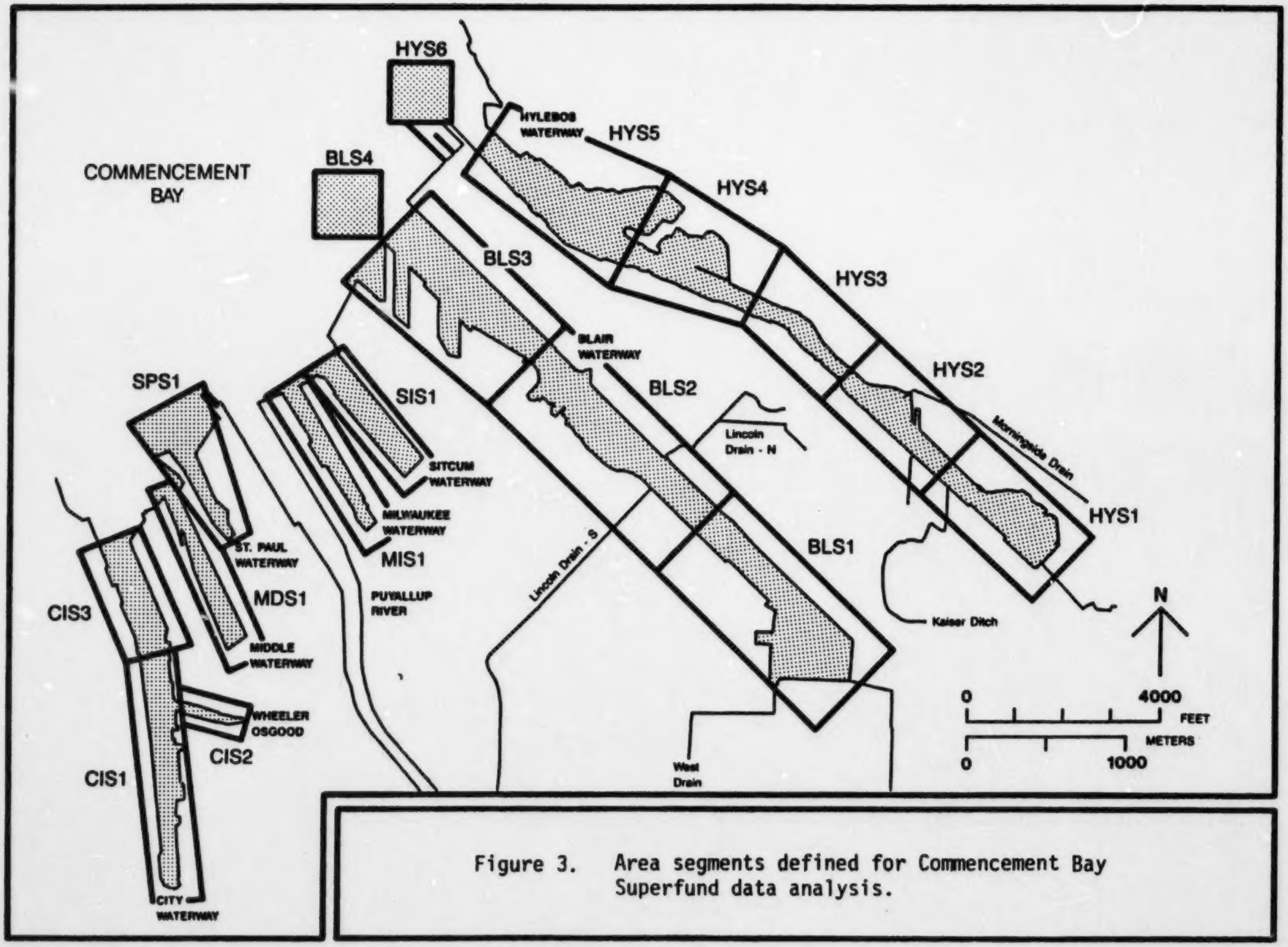

COMMENCEMENT BAY
HYS6
BLS4
HYLEBOS WATERWAY
HYS5
HYS4
HYS3
HYS2
HYS1
Morningside Drain
Kaiser Ditch
BLS3
BLAIR WATERWAY
BLS2
BLS1
Lincoln Drain - N
Lincoln Drain - S
West Drain
SIS1
SITCUM WATERWAY
MILWAUKEE WATERWAY
MIS1
PUYALLUP RIVER
SPS1
ST. PAUL WATERWAY
MDS1
MIDDLE WATERWAY
CIS3
WHEELER OSGOOD
CIS2
CIS1
CITY WATERWAY
N
0
4000
FEET
METERS
0
1000

Figure 3. Area segments defined for Commencement Bay Superfund data analysis.

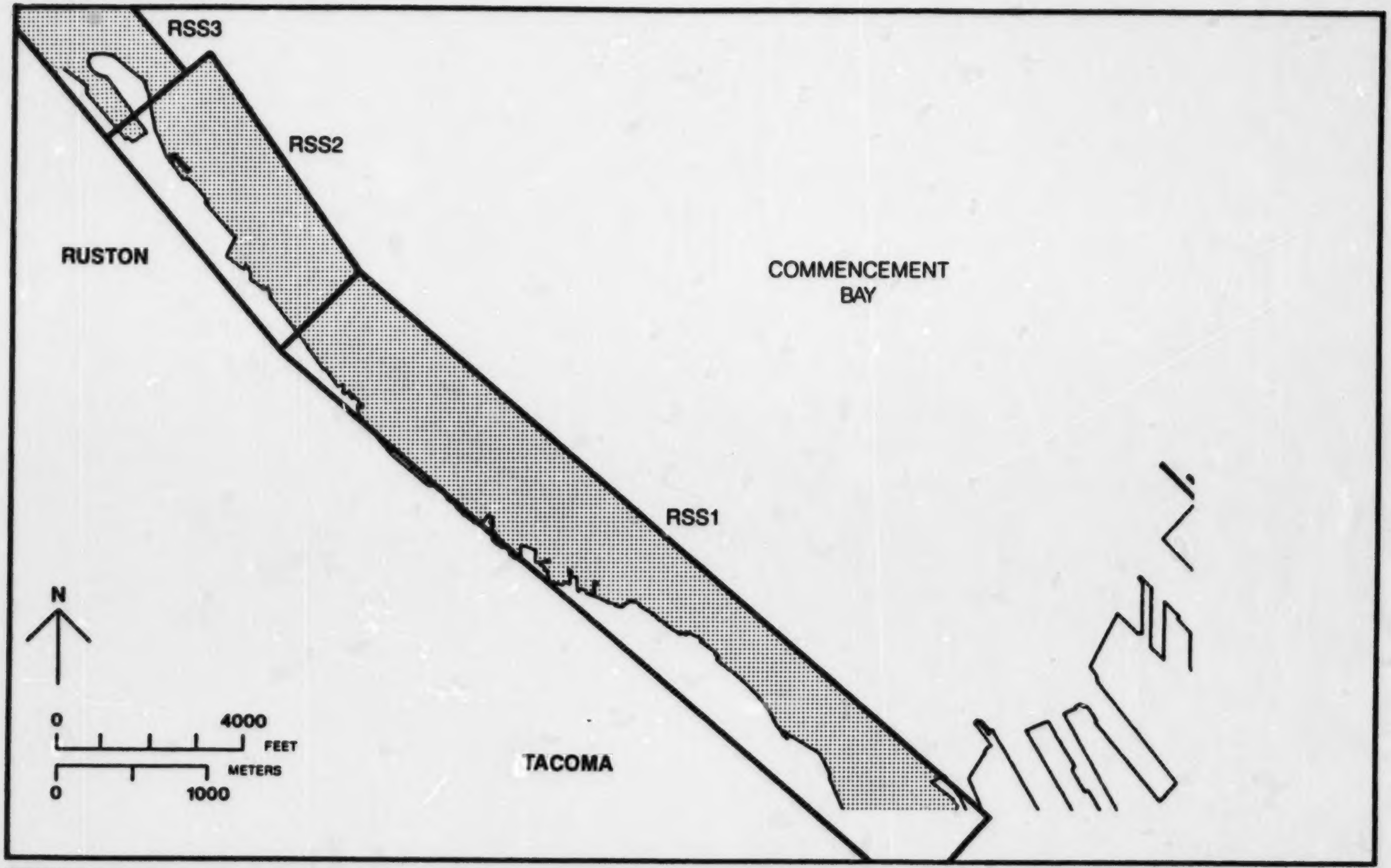

RSS3
RSS2
RUSTON
COMMENCEMENT BAY
RSS1
N
0
4000
FEET
METERS
0
1000
TACOMA

Figure 3. (Continued).

TABLE 2. FINAL RANKING OF PROBLEM AREAS

Segment Containing Problem Area[a]	Environmental Significance	Spatial Extent	Confidence of Source Identification	Total Score
RSS2	4	4	4	12
SPS1	4	3	4	11
CIS1	4	3	4	11
HYS5	4	3	4	11
SIS1	4	4	3	11
HYS1	4	4	3	11
HYS2	4	2	4	10
CIS2	4	1	3	8
MDS1	3	3	2	8
RSS3	1	3	4	8
CIS3	3	2	2	7 [b]
HYS4	3	2	1	6
RSS1a (RS-13)	3	1	1	5
BLS2	2	1	1	4
MIS1	2	1	1	4
RSS1b (RS-15)	1	1	1	3
HYS3	1	1	1	3
BLS1	1	1	1	3
HYS6	1	1	1	3
BLS3	1	1	1	3
BLS4	1	1	1	3

[a] Problem areas did not always encompass an entire segment. Problem areas in the segments indicated are listed in order of their total score for environmental significance, spatial extent, and confidence of source identification.

[b] Identification of potential remedial technologies was conducted for problem areas with a total score greater than or equal to 7.

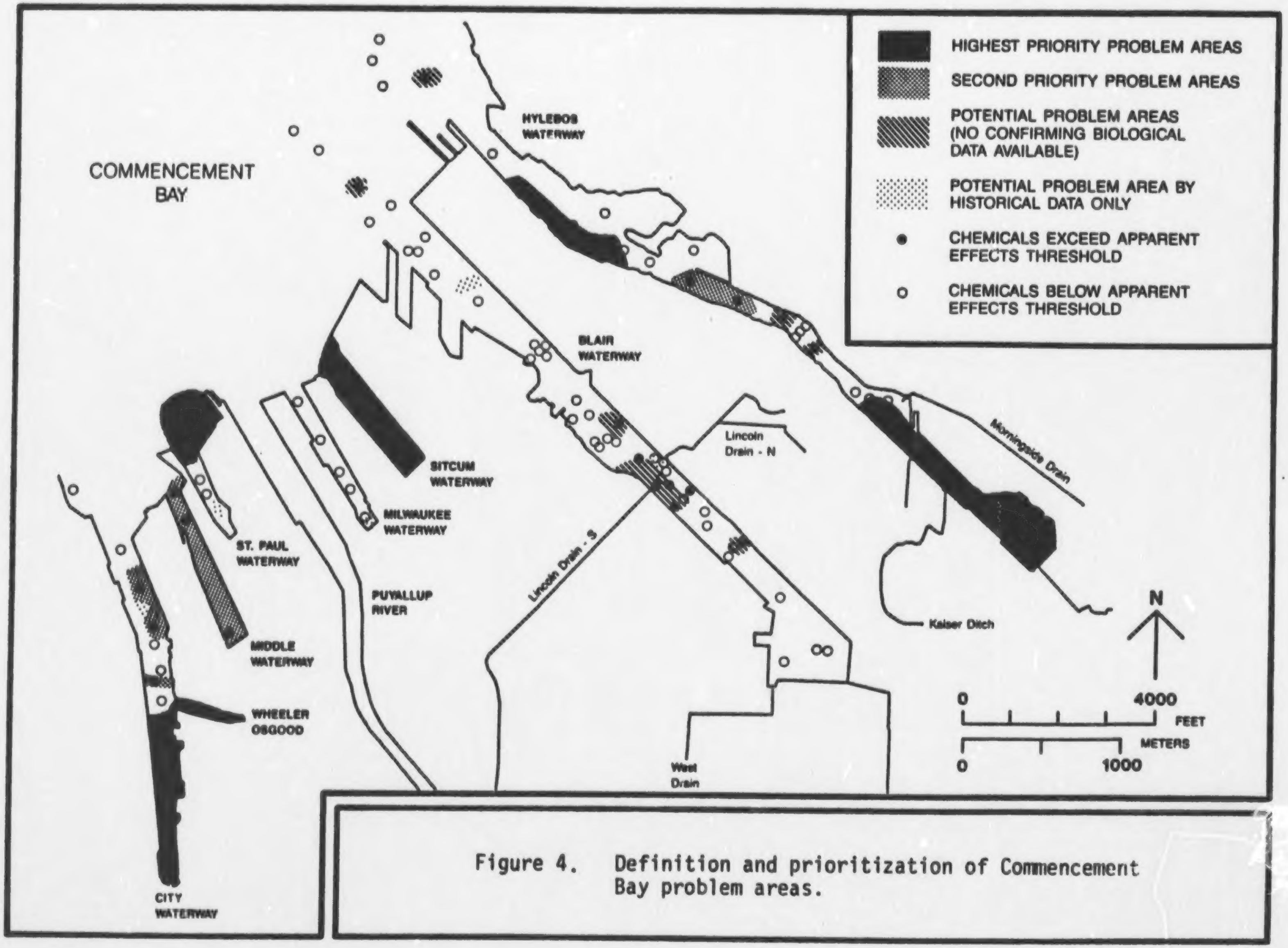

HIGHEST PRIORITY PROBLEM AREAS
SECOND PRIORITY PROBLEM AREAS
POTENTIAL PROBLEM AREAS (NO CONFIRMING BIOLOGICAL DATA AVAILABLE)
POTENTIAL PROBLEM AREA BY HISTORICAL DATA ONLY
CHEMICALS EXCEED APPARENT EFFECTS THRESHOLD
CHEMICALS BELOW APPARENT EFFECTS THRESHOLD
COMMENCEMENT BAY
HYLEBOS WATERWAY
BLAIR WATERWAY
SITCUM WATERWAY
MILWAUKEE WATERWAY
PUYALLUP RIVER
ST. PAUL WATERWAY
MIDDLE WATERWAY
WHEELER OSGOOD
CITY WATERWAY
Lincoln Drain - N
Lincoln Drain - S
West Drain
Morningside Drain
Kaiser Ditch
N
0
4000
FEET
METERS
0
1000

Figure 4. Definition and prioritization of Commencement Bay problem areas.

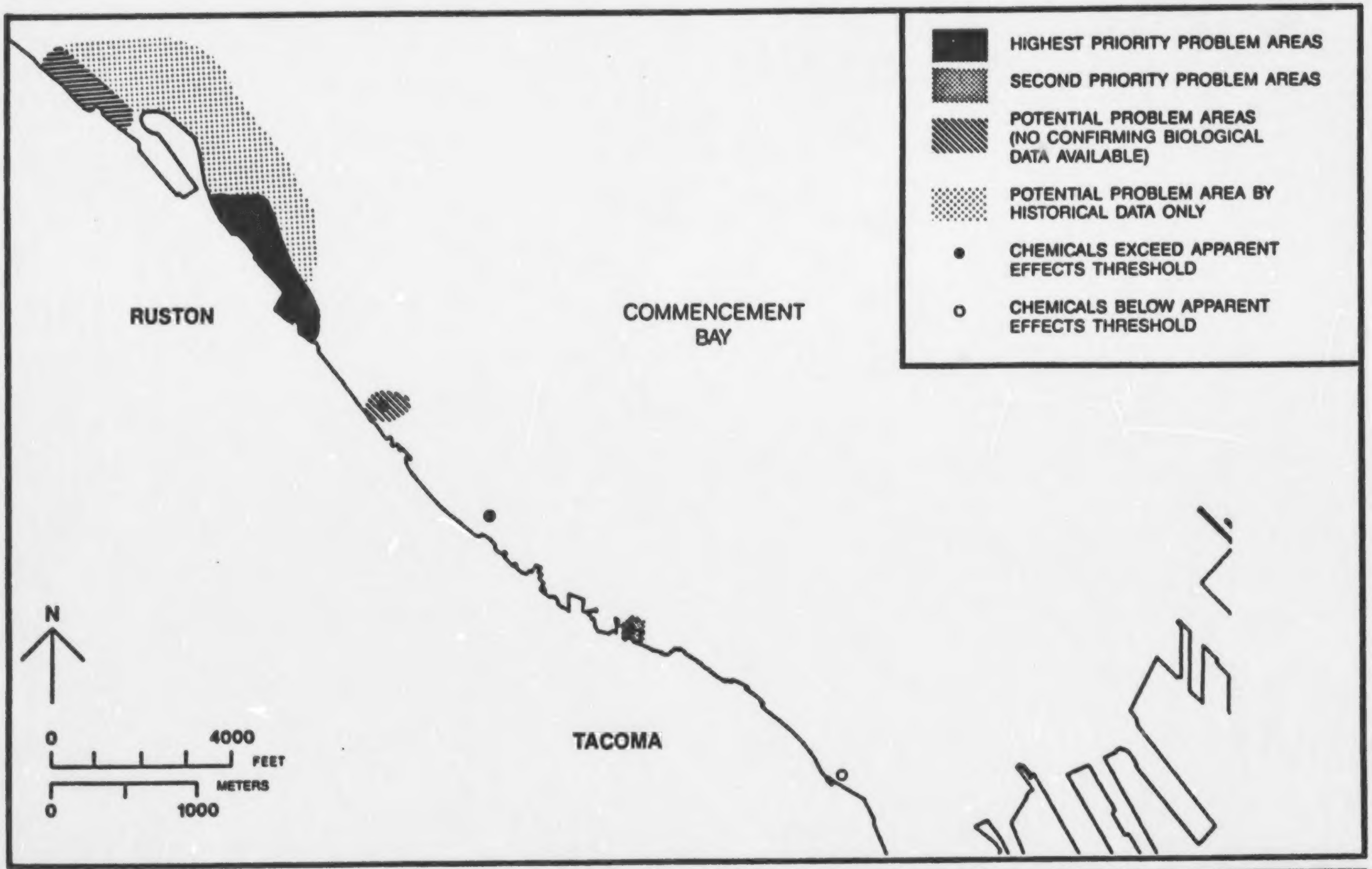

HIGHEST PRIORITY PROBLEM AREAS
SECOND PRIORITY PROBLEM AREAS
POTENTIAL PROBLEM AREAS (NO CONFIRMING BIOLOGICAL DATA AVAILABLE)
POTENTIAL PROBLEM AREA BY HISTORICAL DATA ONLY
● CHEMICALS EXCEED APPARENT EFFECTS THRESHOLD
○ CHEMICALS BELOW APPARENT EFFECTS THRESHOLD
RUSTON
COMMENCEMENT BAY
TACOMA
N
0
4000
FEET
METERS
0
1000

Figure 4. (Continued).

Remedial technologies for the contaminated sediments are classified into three groups: dredging, in situ treatment/stabilization, and capping. These technoloies are discussed in Sections 2.5 and 2.6. The applicability of remedial technologies will be dependent on the specific characteristics and constraints of each problem area. According to an evaluation of alternative dredging methods and equipment (COE 1984), hydraulic dredging is the most effective method for removing sediments with particle-bound (e.g., PCBs, metals) or soluble contaminants (4-methylphenol). The COE (1984) evaluation suggests mechanical dredging methods for removal of sediments contaminated with volatile compounds. These are general recommendations only. Specific site conditions should be evaluated prior to selecting the most effective dredging method for individual problem areas. A Commencement Bay dredging plan that integrates dredging activities (including maintenance dredging, both private and governmental) in the waterways, in addition to other remedial dredging Commencement Bay, should increase the overall cost-effectiveness of all dredging projects.

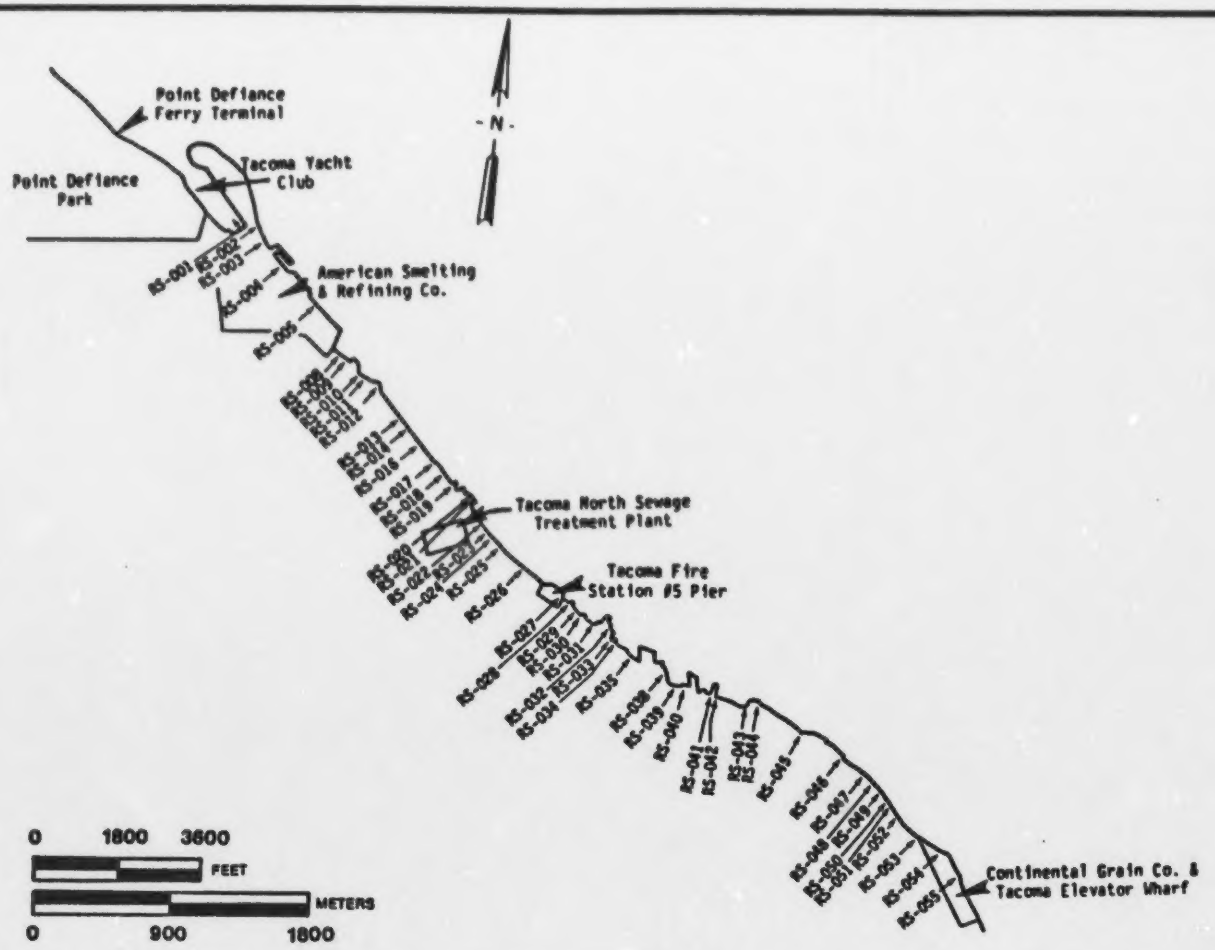
Most in situ treatment/stabilization methods are emerging or new technologies and their effectiveness may be unproven. The National Contingency Plan (NCP) criteria encourage the evaluation of these innovative or advanced technologies. However, these technologies must have a certain degree of effectiveness or they will likely be eliminated based on criteria established for the initial screening process. Therefore, many of the in-situ treatment/stabilization technologies may be eliminated during the initial screening. The applicability of specific in situ technologies should be evaluated during the feasibility study. For most problem areas in the Commencement Bay study area, capping may not be a feasible alternative because of frequent maintenance dredging to provide deep draft depths for the shipping traffic. Again, the specific water depth requirements must be considered when determining the applicability of capping in each problem area.

3.2 RUSTON-PT. DEFIANCE SHORELINE SEGMENT 2

3.2.1 Physical Description

Segment 2 of the Ruston-Pt. Defiance Shoreline extends from the Tacoma Yacht Club to a point approximately 5,900 ft southwest along the shore of Commencement Bay (Figure 5). Facilities located along the Ruston-Pt. Defiance Shoreline Segment 2 include Tacoma Yacht Club and American Smelting and Refining Company (ASARCO). ASARCO discontinued the copper smelting operations in March, 1985, and currently is only operating the arsenic trioxide plant, which may close in the summer of 1985. ASARCO is the only NPDES-permitted facility in Segment 2 (WA0000649). Three outfalls are regulated under this NPDES permit: RS-003 (north outfall), RS-004 (central outfall), and RS-005 (south outfall). Nine non-permitted discharges along Segment 2 release surface water to Commencement Bay. These outfalls are RS-001, RS-002, RS-008, RS-009, RS-010, RS-011, RS-012, RS-013, and RS-014.

Recent subbottom profiling of the Ruston-Pt. Defiance Shoreline (Raven Systems and Research 1984) indicated a bottom slope of approximately 9 percent, and a bottom depth of 120 ft below mean lower low water (MLLW) 800 ft offshore at a point immediately north of ASARCO. Offshore of the ASARCO plant, the bottom slope is uniform at 3 percent to a point approxi-



Point Defiance
Ferry Terminal
Point Defiance
Park
Tacoma Yacht
Club
- N -
American Smelting
& Refining Co.
RS-001
RS-002
RS-003
RS-004
RS-005
RS-010
RS-011
RS-012
RS-013
RS-014
RS-016
RS-017
RS-018
RS-019
Tacoma North Sewage
Treatment Plant
RS-020
RS-021
RS-022
RS-023
RS-024
RS-025
RS-026
Tacoma Fire
Station #5 Pier
RS-027
RS-028
RS-029
RS-030
RS-031
RS-032
RS-033
RS-034
RS-035
RS-038
RS-039
RS-040
RS-041
RS-042
RS-043
RS-044
RS-045
RS-046
RS-047
RS-048
RS-049
RS-050
RS-051
RS-052
RS-053
RS-054
RS-055
Continental Grain Co. &
Tacoma Elevator Wharf
0
1800
3600
FEET
METERS
0
900
1800

Figure 5. Major industries along and discharges to the Ruston-Pt. Defiance Shoreline.

mately 400 ft offshore, where the slope increases to nearly 8 percent. No accumulation of soft muds was observed along the Ruston-Pt. Defiance Shoreline. Sediments there are typically sands, averaging less than 20 percent fine-grained material, and having a clay content of 5 percent. Currently there are no dredging projects planned along the Ruston-Pt. Defiance Shoreline Segment 2. Past dredging projects along the Ruston-Pt. Defiance Shoreline include ASARCO in 1977 and 1983, Industrial Mineral Products in 1980, Crown Pacific Corporation in 1982, and Tacoma Metro Park District (date unknown).

3.2.2. Extent of Contamination

Results of the Commencement Bay Nearshore/Tideflats Remedial Investigation indicate that mercury, arsenic, and low molecular weight hydrocarbons (LPAH) are priority 1 contaminants along the Ruston-Pt. Defiance Shoreline Segment 2. Priority 2 contaminants are high molecular weight hydrocarbons (HPAH), PCBs, cadmium, nickel, copper, zinc, lead, antimony, and dibenzofuran. Priority 3 contaminants are dichlorobenzenes, N-nitrosodiphenylamine, 2-methylphenol, 4-methylphenol, phthalate esters, 1-methyl (2-methylethyl)benzene, biphenyl, dibenzothiophene, methylphenanthrenes, retene, and methylpyrenes. The problem area extends approximately 4,000 ft along the Ruston-Pt. Defiance Shoreline in front of ASARCO. Definition of this problem area is based on biological and chemical analyses of sediment samples collected during this project at Stations RS-16, RS-17, RS-18, RS-19, RS-20, RS-21, and RS-03 (Figure 6); and on evaluation of historical sediment data. Sediment analyses indicated contaminant concentrations above AETs and abnormal biological conditions. Sediment bioassays indicated significant oyster larvae and amphipod toxicity. Low numbers of polychaetes, molluscs, and total benthos were observed. Significant copper accumulations were also found in the muscle tissues of fishes collected along the Ruston-Pt. Defiance Shoreline.

The most extreme metals contamination in Commencement Bay was found in the high-priority area defined in Segment 2. Within this problem area, metals contamination was highest at stations directly off the three outfalls of the ASARCO smelter. It is not clear whether one large or three smaller nearshore hot spots were present, because samples were not collected between the outfalls. Concentrations of metals decreased rapidly both alongshore (toward Stations RS-16 and RS-24) and offshore (toward Stations RS-19 and RS-20). If the high metals concentrations found in the problem area within Segment 2 are associated with the smelter slag or ores, then the spatial extent of the contaminated area could be defined by the physical presence of slag or ores. The high EAR values were likely associated with an effluent component, and the area of extreme EAR may be limited to near the main outfalls. The defined problem area was also highly contaminated with a number of organic compounds, including PAH, PCBs, and 1,4-dichlorobenzene. The spatial distributions of these compounds were not as uniform as were those observed for the metals. The maximum concentrations of individual organic contaminants occurred at different outfall stations. The contaminated area extended east from Segment 2 a considerable distance along the shore, but not to Station RS-15.

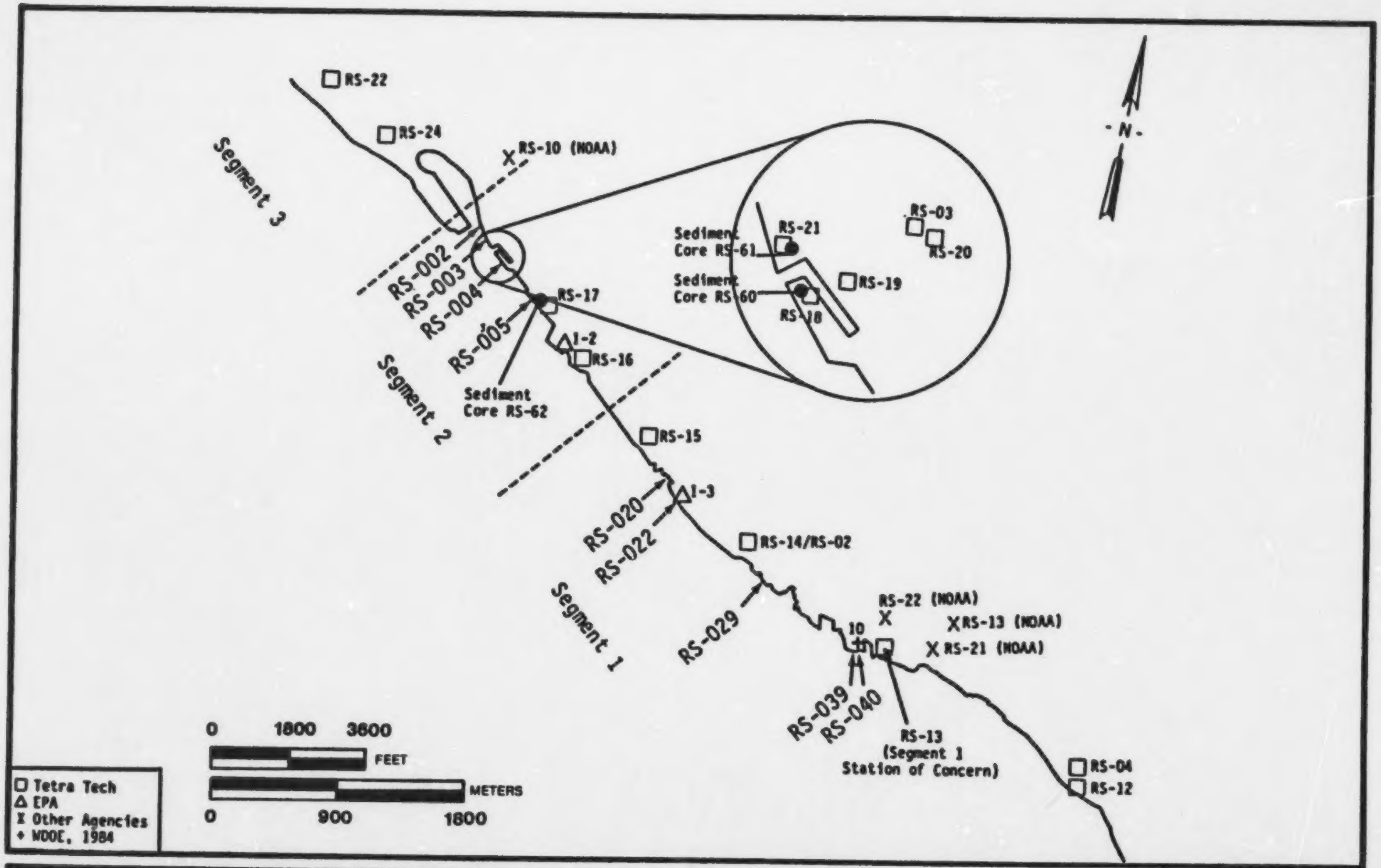

RS-22
RS-24
X RS-10 (NOAA)
Segment 3
RS-002
RS-003
RS-004
RS-005
RS-17
I-2
RS-16
Sediment Core RS-62
Segment 2
RS-21
RS-03
RS-20
Sediment Core RS-61
Sediment Core RS-60
RS-19
RS-18
- N -
RS-15
I-3
RS-020
RS-022
RS-14/RS-02
Segment 1
RS-029
RS-22 (NOAA)
X RS-13 (NOAA)
X RS-21 (NOAA)
10
11
RS-039
RS-040
RS-13 (Segment 1 Station of Concern)
RS-04
RS-12
0
1800
3600
FEET
METERS
0
900
1800
☐ Tetra Tech
△ EPA
X Other Agencies
+ WDOE, 1984

Figure 6. Surficial sediment and sediment core sampling staion locations from all studies along the Ruston-Pt. Defiance Shoreline.

3.2.3 Contaminant Sources

Evaluation of available source information indicates that ASARCO is the confirmed source of arsenic, cadmium, copper, zinc, lead and antimony; and a likely source of the other priority metals (mercury and nickel). Spatial trends indicate ASARCO may also be a source of HPAH, dibenzofuran, dichlorobenzene, and PCBs. Confirmed and potential mechanisms by which contaminants have been entering Commencement Bay from ASARCO include direct waste discharge, surface water runoff, groundwater, and atmospheric release. Although copper smelting ceased at ASARCO in March, 1985, production of arsenic trioxide may continue into the summer. Additional investigation of contaminant transport mechanisms is necessary prior to implementation of source control or sediment remedial action. Further source investigations are also necessary for LPAH, HPAH, PCB, and most of the priority 3 contaminants.

3.2.3.1 ASARCO--

Metals loading from the three ASARCO plant outfalls (RS-003, RS-004, and RS-005) have been summarized in Table 3. Metals loadings from discharge RS-005 (south outfall) are consistently greater than those from the other two ASARCO outfalls. The total metals loadings from all ASARCO outfalls have been estimated to be 478.31 lb/day of arsenic, 154.2 lb/day of copper, 122.2 lb/day zinc, and 13.88 lb/day of lead. These loadings were calculated using average effluent concentrations from one to eight sampling events that occurred prior to plant closure in March, 1985.

Wastes containing metals have probably been discharged from this facility since plant start-up in 1889, and sediment cores collected immediately off the ASARCO outfalls confirm this supposition. Contaminants have been released to Commencement Bay via the discharge of plant process water through outfalls RS-003, RS-004, and RS-005; surface water runoff contaminated with metals; spills of metal ore and Bunker C fuel oil; stack emissions; leaching of metals from slag; and, possibly, contaminated groundwater. Although the relative importance of these mechanisms is not known, it is believed that contaminant loadings from ASARCO will decrease with time. Nevertheless, remedial action may be necessary if the discharges are determined to be major ongoing sources after plant shutdown.

In 1982, the WDOE conducted a RCRA inspection of ASARCO, but determined the company was exempt from these federal regulations. However, WDOE concluded that many ASARCO activities were regulated under the State's Dangerous Waste regulations. Several violations of these regulations were observed at ASARCO during a Dangerous Waste inspection of the facility conducted in March, 1985. Dangerous Waste violations included release of contaminated storm and process waters, contaminated soils, incineration/smelting of wastes, uncontrolled releases of dangerous materials, and overall poor housekeeping. An inspection report detailing the above Dangerous Waste violations and establishing a compliance schedule for the plant closure was signed by WDOE on March 29, 1985, and mailed to ASARCO. It is WDOE's concern that plant closure, including demolition activities, may not consider environmental impacts resulting from additional release of contaminants into the environment. Therefore, WDOE is requiring ASARCO to provide a plan for the plant closure.

TABLE 3. CONTAMINANT LOADINGS AND RELATIVE PERCENTAGE FROM ASARCO, RUSTON-PT. DEFIANCE SHORELINE SEGMENT 2

	RS-003	RS-004	RS-005
Arsenic			
lb/day	0.31	78	400
% of total to segment	0.06	16.31	83.63
Cadmium			
lb/day	<0.012	0.92	10
% of total to segment	0.11	8.42	91.47
Copper			
lb/day	1.2	33	120
% of total to segment	0.78	21.40	77.82
Zinc			
lb/day	0.20	26	96
% of total to segment	0.16	21.28	78.56
Lead			
lb/day	0.28	3.6	10
% of total to segment	2.02	25.94	72.05

ASARCO installed four groundwater monitoring wells on their site in November, 1984. WDOE sampled groundwater from the ASARCO property and analyzed for organic chemicals and metals. Concentrations of organic chemicals were at acceptable levels. Two metals (cadmium and mercury) were detected at concentrations above criteria established for protection of aquatic life as defined by U.S. EPA (1976).

Depending on relative importance of the contaminant transport mechanisms, source control at ASARCO may take many years to achieve, particularly if it is determined that groundwater and leaching of metals from slag are major routes of contamination. If removal of ASARCO slag from the Ruston-Pt. Defiance Shoreline is necessary to meet source control goals, major dredge/fill and excavation operations may be required. Alternatively, if historical and recent contaminant loadings are a result of plant operation (i.e., discharge of plant effluent, fuel and ore spills, stack emissions, and fugitive dust) and contaminated surface water runoff, then source control technologies may be more easily implemented. Source control technologies that may be applicable at the ASARCO facility include

- Surface water controls, Section 2.3
- Mitigation of contaminated soils, including slag deposited along the shoreline (e.g., stabilization of slag with cement)
- Groundwater controls, Section 2.4
- Control of atmospheric releases, including fugitive dust from stock piles of slag and ore concentrations (slag and metal ores at the site should either be covered, containerized, or removed from the site)
- Control of plant demolition to prevent additional release of contaminants into the environment.

3.2.3.2 Unknown Sources--

ASARCO has been identified as the source for most of the priority 1 and 2 contaminants in Ruston-Pt. Defiance Shoreline Segment 2 based on historical practices, spatial gradients of contamination and benthic effects, and effluent sampling data. Priority 3 contaminants for which source identification was not possible with existing data are dibenzofuran, dichlorobenzenes, N-nitrosodiphenylamine, 2-methylphenol, 4-methylphenol, phthalate esters, dibenzofuran, 1-methyl(2-methylethyl)benzene, biphenyl, dibenzothiophene, methylphenanthrenes, retene, and methylpyrenes. ASARCO is a potential source of LPAH, HPAH, and PCB, but additional investigation is necessary to confirm this.

3.2.4 Sediment Remedial Actions

Sediments along the Ruston-Pt. Defiance Shoreline off ASARCO have been assigned an environmental significance ranking of 4 based on observed contamination levels, toxicity, and biological effects. It is therefore recommended that this problem area be evaluated for sediment remedial action to reduce the environmental and public health threat associated with the priority contaminants. Remediation of the existing contaminated sediments should be implemented only after the present sources have been effectively controlled. Options for management of contaminated sediments along the Ruston-Pt. Defiance Shoreline Segment 2 include capping, in situ treatment/stabilization, and dredging. Capping may be a viable option in this segment, since closure of the ASARCO facilities may reduce large vessel shipping traffic that often requires deep water depths. In general, priority contaminants along the Ruston-Pt. Defiance Shoreline are sediment-bound. Although hydraulic dredging appears to be the most effective sediment removal method, mechanical dredging methods should be evaluated if sediment removal is considered an appropriate remedial action. Levels of organic chemicals decreased significantly in the deepest horizon (0.41-0.44 m) of sediment core RS-61, but concentrations of metals were all significantly above AET values. Therefore, the vertical extent of contamination along the Ruston-Pt. Defiance Shoreline cannot be determined with existing core data and the volume of contaminated sediment in this problem area cannot be estimated at this time.

3.2.5 Data Needs

Several data gaps for the Ruston-Pt. Defiance Shoreline Segment 2 hinder the development and evaluation of specific source control and sediment remedial action alternatives. Data needs specific to this problem area include

- Additional source investigation for priority contaminants listed in Section 3.3.3.2:

  Priority 1 - LPAH
  Priority 2 - HPAH, PCBs, dibenzofuran
  Priority 3 - dichlorobenzenes, N-nitrosodiphenylamine, 2-methylphenol, 4-methylphenol, phthalate esters, 1-methyl(2-methylethyl)benzene, biphenyl, dibenzothiophene, methylphenanthrenes, retene, and methylpyrenes

- Definition and quantification of contaminant transport mechanisms from ASARCO, including stormwater runoff, groundwater, and leaching from slag used to stabilize the shoreline

- Spatial extent of the problem area, as determined by surface sediment samples from beyond nearshore Station RS-17 (both parallel and perpendicular to shore)

- Vertical extent of contaminated sediments, as determined by deep core sampling

- Determination of sedimentation rate and the potential for the problem area to be capped by natural sedimentation of clean materials.

3.3 ST. PAUL WATERWAY SEGMENT 1

3.3.1 Physical Description

St. Paul Waterway is located between the Puyallup River to the north and Middle Waterway to the south (Figure 7). Champion International occupies most of the land surrounding St. Paul Waterway, including the area north to the Puyallup River and the area to the east bounded by East 11th Street. Available information indicates that only forest products industries have historically occupied the land surrounding St. Paul Waterway. Champion International is the only permitted discharge to St. Paul Waterway (SP-189, NPDES WA0000850). Non-permitted discharges include the St. Paul storm drain outfalls SP-268-01 and SP-268-02, located at the head of the waterway; a 10-in corrugated steel pipe outfall located on the north bank immediately west of the Champion International clarifiers (SP-269); and groundwater seeps located about halfway along the north shore below the main Champion International manufacturing plant (SP-706).

St. Paul Waterway is approximately 2,000 ft in length. Its width ranges from 400 ft at the head to 600 ft at the mouth. The depth of St. Paul Waterway increases from the head toward the mouth. Recent subbottom profiling of St. Paul Waterway indicated mid-channel depths typically ranging from less than 10 ft below MLLW at the head of the waterway to greater than 30 ft below MLLW at the mouth, with fairly steep channel sides (Raven Systems and Research 1984). Sediment accumulation was between 1 and 4 ft, with most occurring along the north side and at the mouth (Raven Systems and Research 1984). Sediments within St. Paul Waterway are typically 50 percent fine-grained material, with a clay content of nearly 10 percent (Tetra Tech 1985). The present configuration of St. Paul Waterway is the result of a dredge and fill project by the U.S. Army Corps of Engineers; the head of the waterway was filled to East 11th Street in 1960. There have been no dredging projects in St. Paul Waterway within the last 10 yr and there are no proposed projects at this time (Kucinski, G., 6 August 1985, personal communication)

3.3.2 Extent of Contamination

Results of the Commencement Bay Nearshore/Tideflats Remedial Investigation indicate that 4-methylphenol is the only priority 1 contaminant in St. Paul Waterway. Priority 2 contaminants include benzyl alcohol, 1-methyl(2-methylethyl)benzene, and 2-methoxyphenol. Priority 3 contaminants are nickel, LPAH, 2-methylphenol, phenol, biphenyl, diterpenoid hydrocarbons, retene, total volatile solids, and total organic carbon. The area of concern is located at the mouth of the waterway, based on biological and chemical analyses of sediments collected during this project at Stations SP-13, SP-14, SP-15, and SP-16 (Figure 8), and on evaluation of historical sediment data. Analyses indicate contaminant concentrations at all stations and several abnormal biological conditions. Sediment bioassays indicated significant oyster larvae and amphipod toxicity. Benthic analyses indicated low mollusc counts. Fish caught in St. Paul Waterway had significant copper accumulation in muscle tissues.

Sediment contamination at the mouth of St. Paul Waterway differed considerably from that in all other Commencement Bay areas. None of the

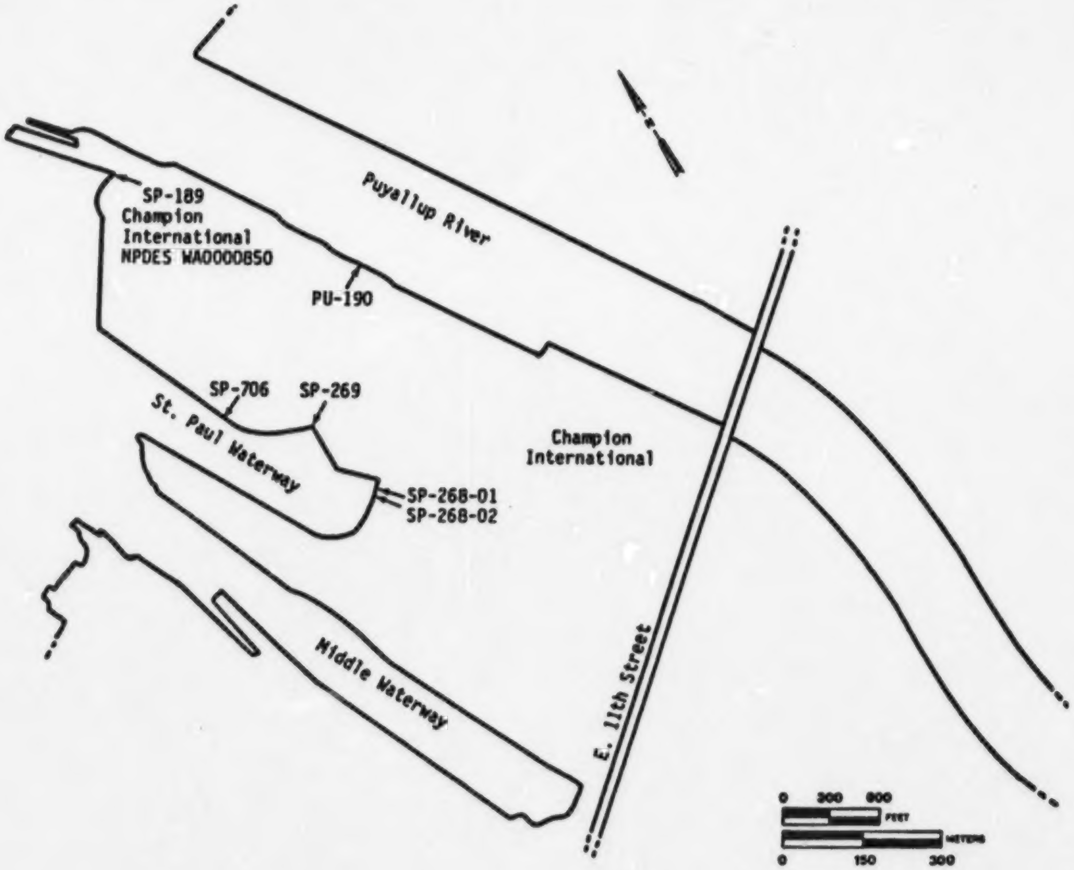

Puyallup River
SP-189
Champion
International
NPDES WA0000850
PU-190
SP-706
SP-269
St. Paul Waterway
SP-268-01
SP-268-02
Champion
International
Middle Waterway
E. 11th Street
0
300
600
FEET
METERS
0
150
300

Figure 7. Major industries along and discharges to St. Paul Waterway.

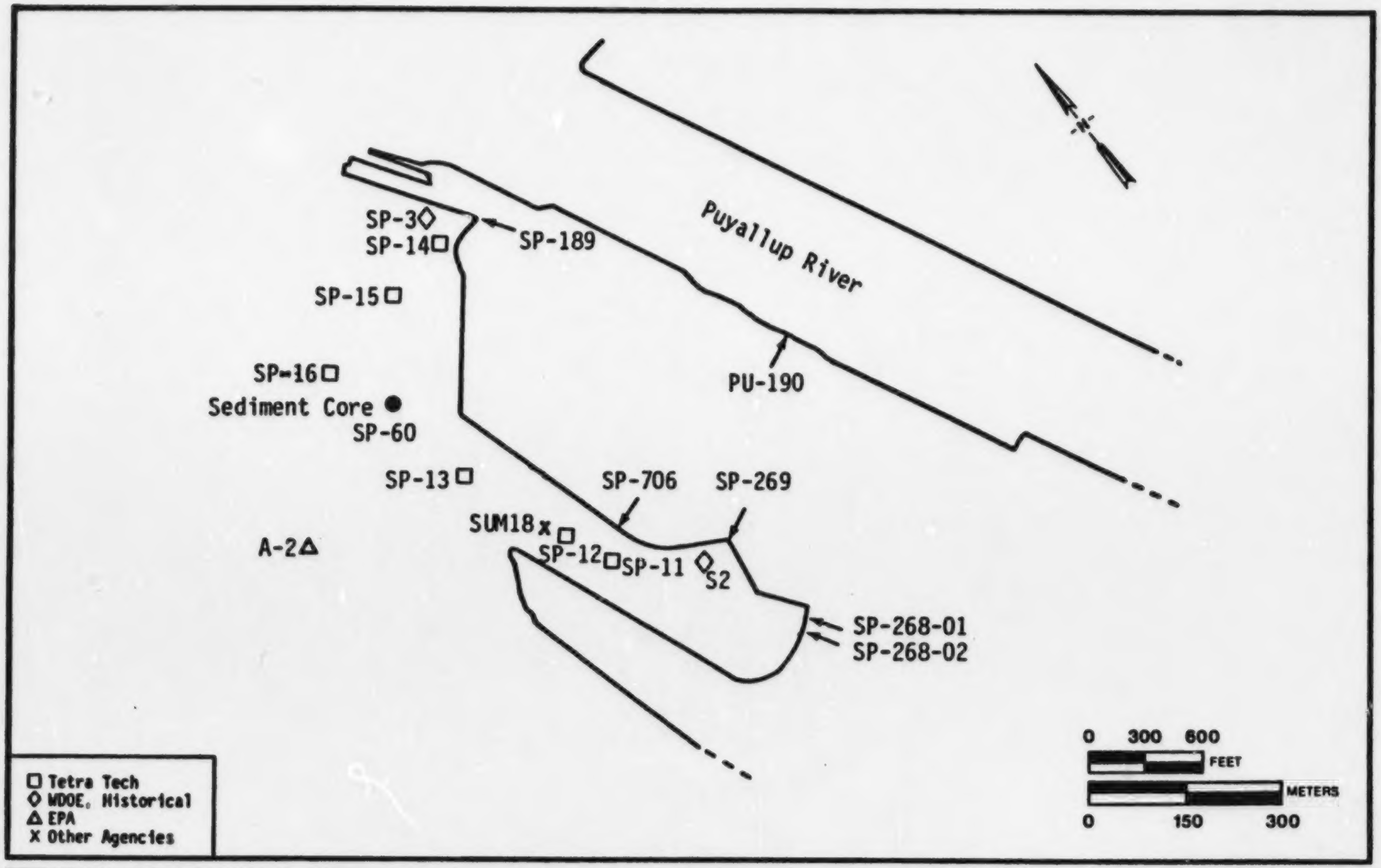

Puyallup River
SP-3
SP-14
SP-189
SP-15
SP-16
Sediment Core
SP-60
PU-190
SP-13
SP-706
SP-269
SUM18
SP-12
SP-11
S2
A-2
SP-268-01
SP-268-02
N
☐ Tetra Tech
◇ WDOE, Historical
△ EPA
X Other Agencies
0 300 600
FEET
METERS
0 150 300

Figure 8. Surficial sediment and sediment core sampling station locations from all studies in St. Paul Waterway.

HPAH, PCBs, metals, or chlorinated benzenes were present in particularly high concentration at this site, except for limited copper enrichment (below its AET) at Station SP-14, located off the outfall of the Champion International pulp mill. Methylated phenols (especially 4-methylphenol) and LPAH were the characteristic contaminants of the problem area. These compounds all exceeded toxicity and benthic AET near the outfall. Concentrations of these compounds decreased abruptly away from the outfall. Many additional hydrocarbons and substituted phenols were probably present in these sediments, but were not directly measured. It was apparent in data from St. Paul Waterway and also from adjacent waterways that at least 2-methoxyphenol had been transported to other areas of Commencement Bay. Typically, transport of contaminants is not observed between waterways. But since the Champion International outfall is located in Commencement Bay, and not within isolated waters of a specific waterway, transport of contaminants from that outfall is likely.

3.3.3 Contaminant Sources

Source identification in St. Paul Waterway concluded that Champion International is the confirmed source of several contaminants and the probable source of many other contaminants identified in the problem area. Champion is also the largest confirmed source of organic materials and suspended solids to St. Paul Waterway. Biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total suspended solids (TSS) loadings are very large (7,000-130,000 lb/day of each). Because discharges to St. Paul Waterway have not been analyzed for most of the priority contaminants, source identification was by inference. Most contaminants were linked to pulp and paper manufacturing and were presumed to be in the effluent from Champion International or derived from precursors in the effluent. The Puyallup River is the largest source of copper, solids, and organic matter to Commencement Bay, but loading to St. Paul Waterway from the river following dilution with Commencement Bay waters is uncertain. Loadings of naphthalene and copper from Champion are the largest to St. Paul Waterway. Although these contaminants were not defined as "priorities" in St. Paul Waterway, copper and naphthalene compounds exhibited high EAR in surficial sediments. Receiving water sampling performed by WDOE in 1981 showed that copper concentrations near the plant outfall of Champion International (then St. Regis Paper Company) exceeded the U.S. EPA maximum allowable concentration for saltwater. Chloroform was also detected above background levels, but there are no applicable water quality criteria for this contaminant. Storm drains SP-268-01 and SP-268-02 are confirmed sources of naphthalene, copper and suspended solids. Loadings are estimated to be 0.00043 lb/day of naphthalene, 0.036 lb/day of copper, and 303 lb/day of suspended solids.

In general, control of contaminants from Champion International should receive top priority, since this is the major source of most, if not all, contaminants to St. Paul Waterway. Less emphasis should be placed on control of discharges SP-268-01 and SP-268-02 since they are relatively minor sources, and although no contaminant loading data exist for these discharges, the priority contaminants in St. Paul Waterway are not ones typically found in storm water.

3.3.3.1 Champion International--

Champion International is most likely the largest source of suspended solids and organic matter, depending on the actual loading from the Puyallup River. Champion is also the major indicated source of the other priority contaminants, including 4-methylphenol, 1-methyl(2-methylethyl)benzene, 2-methoxyphenol, and 2-methylphenol because of their association with pulp and paper manufacturing or their potential derivation from precursors (e.g., lignin from pulp discharges). Non-priority contaminants associated with Champion International are copper, naphthalene, and chloroform. These contaminants have been detected in the plant effluent and the receiving water off Champion International. Naphthalene loading from Champion International was estimated to be 1.2 lb/day, and copper loading was estimated to be 27 lb/day. Characterization of Champion International effluent is recommended, focusing specifically on the priority contaminants and their possible precursors. Once Champion International is confirmed as the source of these priority pollutants, reduction of contaminant loading to St. Paul Waterway will be recommended at Champion International through in-plant operation, process controls, and/or additional waste treatment. In-plant source controls are specific to each manufacturing process, and were not within the scope of this report. It is recommended that Champion International monitor plant effluent for 4-methylphenol and its precursors, and investigate alternatives to reduce the discharge of these wastes through modification of in-plant controls and/or additional waste treatment.

3.3.3.2 Unknown Sources--

For several of the priority contaminants identified in St. Paul Waterway, no confirmed sources have been identified. Champion International is the presumed source of these contaminants, based on their spatial distributions, and their association with pulp and paper manufacturing. However, their presence in Champion International effluent has not been confirmed. Contaminants for which source confirmation is necessary are 4-methylphenol, benzyl alcohol, 1-methyl(2-methylethyl)benzene, 2-methoxyphenol, nickel, LPAH, 2-methylphenol, phenol, biphenyl, and diterpenoid hydrocarbons, and retene. Given their ubiquitous distribution, there are probably sources of LPAH to St. Paul Waterway other than Champion International. Diterpenoid hydrocarbons (including retene) may also be derived from the transport of coal particles in the Puyallup River.

3.3.4 Sediment Remedial Actions

Sediments at the mouth of St. Paul Waterway have been assigned an environmental significance ranking of 4, based on observed contamination levels, toxicity, and biological effects. This problem area may be able to recover through natural degradation processes, since the priority contaminants are organic enrichment and soluble compounds that typically do not persist in the environment. This "natural cleansing" process occurred near sewage outfalls and pulp mill outfalls within Everett Harbor when discharges from these sources were discontinued. Additional information is necessary to determine if this process occurs within a time frame that is consistent with WDOE's remedial action goals. Champion International is planning to extend their outfall into deeper water within Commencement Bay. Champion International is required to submit the plans, specifications, and construction schedule for this improvement to WDOE by October 1, 1985. Once the discharge has been diverted to deeper water, benthic monitoring is recommended at the old outfall site to determine the rate of recovery. If sediment chemical analyses and benthic monitoring indicate recovery at an acceptable rate with no additional adverse effects, sediment remedial actions may not be necessary. If this option proves unacceptable, evaluation of sediment remedial actions may be necessary to reduce the environmental threat associated with the priority contaminants in the sediments. Remediation of the existing contaminated sediments should be implemented only after the present sources of the contaminantion have been effectively controlled.

Options for management of contaminated sediments at the mouth of St. Paul Waterway include dredging, in situ treatment/stabilization, and capping. Sediment management technologies are discussed in Chapter 2 of this report.

In general, the priority contaminants are classified as primarily soluble. The volume of contaminated sediments at the mouth of St. Paul Waterway is estimated at 129,067 yd^3, using a surface area of 32 ac, computed with a planimeter, and an average sediment depth of 2.5 ft, estimated from recent subbottom profiles (Raven Systems and Research 1984). For the purpose of this preliminary volume calculation, contamination was assumed to extend through the soft sediment layer. However, it may extend into the harder underlying sediment layers. Additional deep core sampling is necessary to determine the actual vertical extent of contamination.

3.3.5 Data Needs

Several data gaps exist for St. Paul Waterway that hinder the development and evaluation of specific source control and sediment remedial action alternatives. Data gaps for St. Paul Waterway are associated with non-definitive boundaries of problem areas, or with the inconclusive identification of potential sources. Data needs specific to the St. Paul Waterway include

- Characterization of the effluent from Champion International for the priority contaminants listed in Section 3.4.3.2:

  Priority 1 - 4-methylphenol
  Priority 2 - benzyl alcohol, 1-methyl(2-methylethyl)benzene, 2-methoxyphenol
  Priority 3 - nickel, LPAH, 2-methylphenol, phenol, biphenyl, diterpenoid hydrocarbons

- More precise definition of the spatial and vertical extent of contamination as determined by surface sediment and deep core sampling

- Potential recovery rate of the problem area once the source has been discontinued

- Determination of sedimentation rate and the potential for capping by natural sedimentation of clean materials.

3.4 CITY WATERWAY SEGMENT 1

3.4.1 Physical Description

Segment 1 of City Waterway extends from the head of the waterway to the 11th Street Bridge (approximately 3,500 ft from the mouth), excluding the Wheeler-Osgood branch. Several businesses are located along the banks of this segment. Woodworth and Company, Martinac Shipbuilding, Pickering Industries, American Plating, and City Marina facilities are located along the east shore. Harmon Furniture, J.H. Galbraith Co., George Scofield Co., Tru-mix, Johnny's Seafoods, Colonial Fruit and Produce, Western Fish and Oyster Co., and MSA Saltwater Boats are located along the west shore (Figure 9). Permitted discharges to City Waterway Segment 1 are George Scofield Co. (CI-232, NPDES WA0003298) and Western Fish and Oyster Co. (CI-227, NPDES WA0022853). Atlas Foundry, located at the head of City Waterway, is permitted to discharge noncontact process water to CN-237 (NPDES WA0022918). There are 24 non-permitted stormwater discharges to City Waterway Segment 1 (Figure 10), including CN-237 (Nalley Valley), CS-237 (south Tacoma), and CI-230 (15th Street).

City Waterway Segment 1 is approximately 4,500 ft in length and varies in width between 400 ft and 600 ft, with very irregular shorelines. This segment is congested with docking areas, pleasure craft, and small shipping vessels. The depth of City Waterway increases from the head toward the mouth. Recent subbottom profiling of City Waterway indicated mid-channel depths typically ranging from less than 10 ft below MLLW at the head of the waterway to approximately 30 ft below MLLW at the 11th Street bridge (Raven Systems and Research 1984). Significant sediment accumulation occurs in City Waterway primarily as a result of storm sewer discharges. Sediment accumulation is estimated to be greater than 10 ft deep at the head of the waterway and decreases to approximately 3 ft underneath the 11th Street bridge. Sediments within City Waterway are typically 64 percent fine-grained material with an average clay content of 18 percent. These sediments are described as anoxic with a very high organic content (nearly 9 percent). Between 1905 and 1948, the waterway was dredged every 3 to 12 yr. City Waterway has not been dredged by the U.S. Army Corps of Engineers since 1948. Past dredging projects in City Waterway Segment 1 include the city of Tacoma in 1975, Johnny's Dock Restaurant and Pickering Industries in 1977, Morris and Sons in 1978, M.W. Perrow in 1979, S. Jones in 1981, and J.E. Meaker in 1982. The only dredging activity proposed in City Waterway is at City Marina.

3.4.2 Extent of Contamination

Results of the Commencement Bay Nearshore/Tideflats Remedial Investigation indicate that priority 1 contaminants in City Waterway Segment 1 are mercury, zinc, lead, and total organic carbon. Priority 2 contaminants are HPAH, cadmium, nickel, copper, LPAH, 2-methylphenol, 4-methylphenol, phthalate esters, and oil and grease. Priority 3 contaminants are dichlorobenzenes, N-nitrosodiphenylamine, aniline, and benzyl alcohol. The area of concern is defined as the main channel from the head to the 11th Street bridge, based on biological and chemical analyses of sediments collected during this project at stations CI-01, CI-03, CI-11, CI-12, CI-13, CI-14, CI-15, CI-17, and CI-18 (Figure 11), and on evaluation of historical sediment

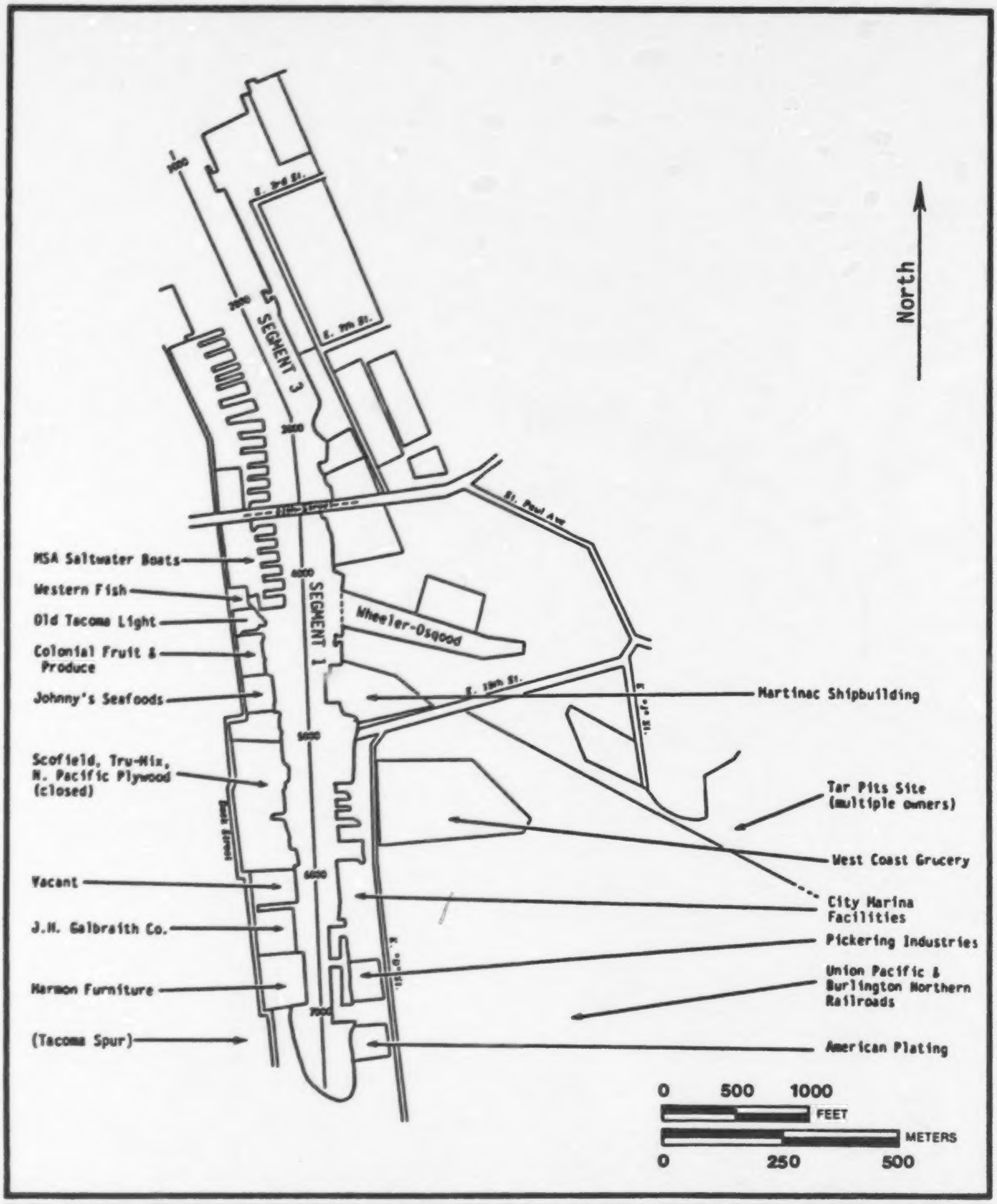

1000
E. 3rd St.
2000
SEGMENT 3
E. 9th St.
3000
11th Street
St. Paul Ave
North
MSA Saltwater Boats
Western Fish
Old Tacoma Light
Colonial Fruit & Produce
Johnny's Seafoods
Scofield, Tru-Mix, N. Pacific Plywood (closed)
Vacant
J.H. Galbraith Co.
Harmon Furniture
(Tacoma Spur)
4000
SEGMENT 1
Wheeler-Osgood
E. 15th St.
5000
6000
7000
Dock Street
Martinac Shipbuilding
Tar Pits Site (multiple owners)
West Coast Grocery
City Marina Facilities
Pickering Industries
Union Pacific & Burlington Northern Railroads
American Plating
0
500
1000
FEET
METERS
0
250
500

Figure 9. Industries surrounding City Waterway Segment 1.

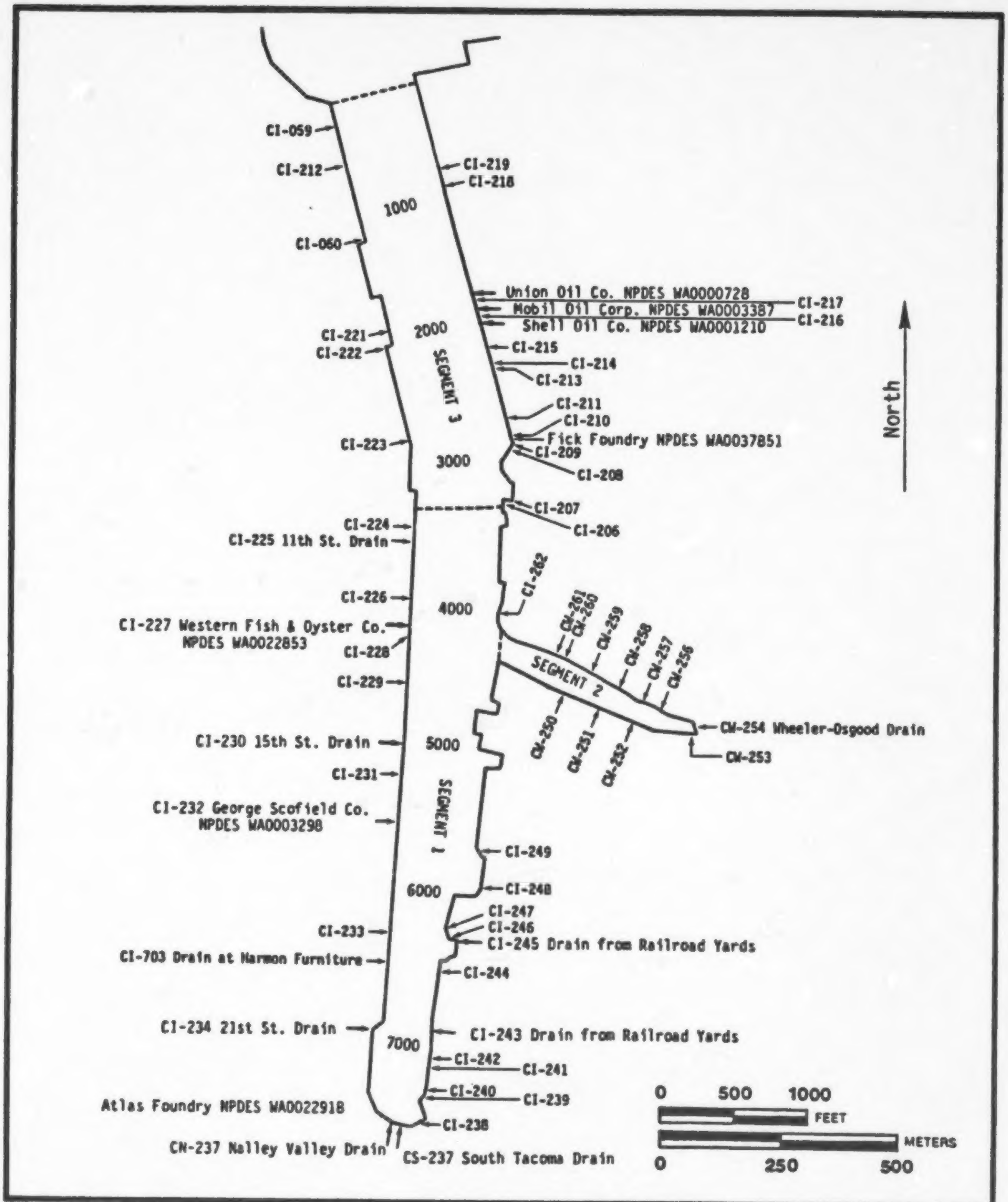

CI-059
CI-212
CI-219
CI-218
1000
CI-060
Union Oil Co. NPDES WA0000728
Mobil Oil Corp. NPDES WA0003387
Shell Oil Co. NPDES WA0001210
CI-217
CI-216
CI-221
CI-222
2000
SEGMENT 3
CI-215
CI-214
CI-213
North
CI-211
CI-210
Fick Foundry NPDES WA0037851
CI-209
CI-223
3000
CI-208
CI-207
CI-206
CI-224
CI-225 11th St. Drain
CI-262
CI-226
4000
CW-261
CW-260
CW-259
CW-258
CW-257
CW-256
CI-227 Western Fish & Oyster Co.
NPDES WA0022853
CI-228
SEGMENT 2
CI-229
CW-250
CW-251
CW-252
CW-254 Wheeler-Osgood Drain
CW-253
CI-230 15th St. Drain
5000
CI-231
SEGMENT 1
CI-232 George Scofield Co.
NPDES WA0003298
CI-249
6000
CI-248
CI-247
CI-246
CI-245 Drain from Railroad Yards
CI-233
CI-703 Drain at Harmon Furniture
CI-244
CI-234 21st St. Drain
7000
CI-243 Drain from Railroad Yards
CI-242
CI-241
CI-240
CI-239
Atlas Foundry NPDES WA0022918
CI-238
CN-237 Nalley Valley Drain
CS-237 South Tacoma Drain
0
500
1000
FEET
METERS
0
250
500

Figure 10. NPDES-permitted and non-permitted discharges to City Waterway.

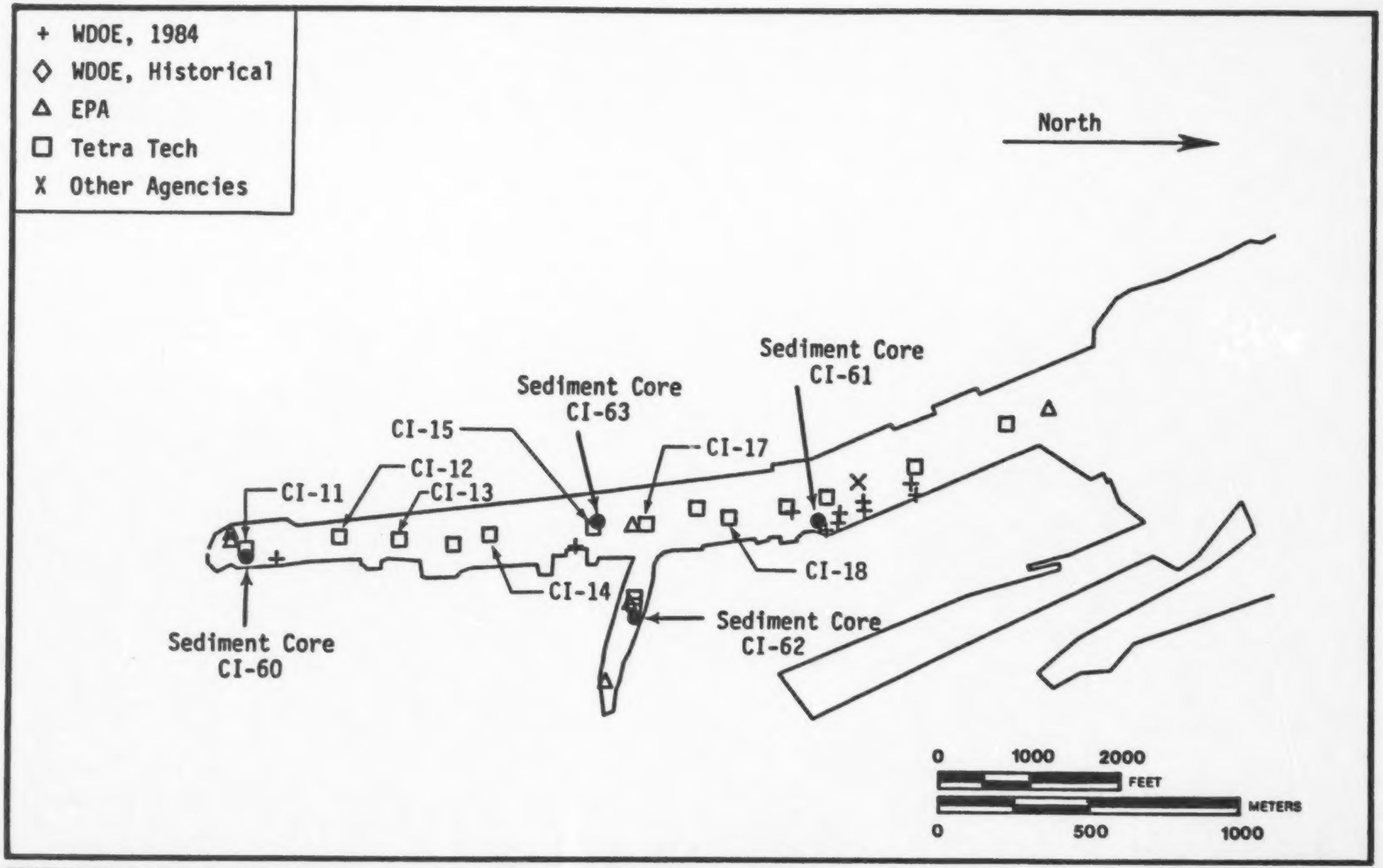

+ WDOE, 1984
◇ WDOE, Historical
△ EPA
□ Tetra Tech
X Other Agencies
North
Sediment Core CI-61
Sediment Core CI-63
CI-15
CI-17
CI-12
CI-11
CI-13
CI-14
CI-18
Sediment Core CI-62
Sediment Core CI-60
0
1000
2000
FEET
METERS
0
500
1000

Figure 11. Surficial sediment and sediment core sampling station locations from all studies in City Waterway.

data. Analyses indicated contaminant concentrations exceeding AET values at all stations and several abnormal biological conditions. Sediment bioassays indicated significant oyster larvae and amphipod toxicity. Benthic analyses indicated low mollusc counts. Fish in City Waterway had significant accumulations of PCBs in muscle tissue.

Within the waterway, lead exhibited one of the most consistent concentration gradients of any substance in any Commencement Bay study area. Sediment lead concentrations at the head of the waterway were among the highest observed in any sediment away from Segment 2 of the Ruston-Pt. Defiance Shoreline. Lead concentrations decreased regularly from a maximum at Station CI-11 (at the head of the waterway) to levels comparable to those elsewhere in the study area toward the mouth of the waterway. A similar gradient in percent organic carbon was observed from the head of the waterway to the mouth. PAH concentrations generally decreased from the head of the waterway along the main channel of City Waterway, but maximum PAH concentrations were observed at Station CI-12 rather than CI-11. Chlorinated benzenes, especially 1,4-dichlorobenzene, were found at high concentrations only at the head of the waterway in Segment 1.

3.4.3 Contaminant Sources

Source identification for City Waterway Segment 1 indicates that the two 96-in storm drains at the head of the waterway are the largest known source of zinc, lead, cadmium, nickel, and organic matter to City Waterway. Contaminant loadings for the storm drains that discharge to City Waterway and the Wheeler-Osgood branch of City Waterway are presented in Table 4. Stormwater runoff from south Tacoma and the Nalley Valley is discharged to City Waterway via CS-237 and CN-237, respectively. Storm water from these two drains accounts for nearly 92 percent of the total storm water discharged to City Waterway (excluding the Wheeler-Osgood branch). WDOE sampled 10 storm drains that discharge to City Waterway Segment 1 and the Wheeler-Osgood branch as part of the Commencement Bay Nearshore/Tideflats Remedial Investigation (Johnson and Norton 1984). In general, contaminant loadings from most other storm drains to City Waterway Segment 1 were much smaller than those from CS-237 and CN-237; however, the 15th Street drain (CI-230) was determined to be the largest source of mercury, LPAH, and HPAH to City Waterway Segment 1. Metals loading from CI-230 was ranked second for cadmium, and third for zinc and lead. In an effort to identify and document sources of metals to City Waterway (Norton and Johnson 1984), WDOE studied sediments near three industries thought to be likely sources of metals to City Waterway: American Plating and Martinac Shipbuilding, located along the east shore of City Waterway Segment 1, and Fick Foundry, located in Segment 3. No problem was identified with the activities at Fick Foundry. Metals concentrations in sediments near Martinac Shipbuilding were substantially elevated with respect to other sediments within City Waterway and Commencement Bay (Norton and Johnson 1984). Concentrations of nickel in surficial sediments near American Plating were higher than those observed in adjacent sediment samples. Silver and chromium were non-priority contaminants observed at higher levels in surficial sediments near American Plating than in sediments from adjacent areas. Concentrations of the priority contaminants of mercury, zinc, copper, and lead, and the non-priority contaminants of arsenic and beryllium near American Plating

TABLE 4. CONTAMINANT LOADINGS AND RELATIVE PERCENTAGES FOR CITY WATERWAY AND THE WHEELER-OSGOOD BRANCH OF CITY WATERWAY

	CI-225 (S 11th St)	CI-230 (S 15th St)	CI-234 (S 21st St)	CI-243 (E 21st St)	CI-245 (E 19th St)	CI-248 (E 18th St)	CI-703 (Below Harmons)	CN-237 Nalley Valley	CS-237 (South Tacoma)	CW-254[a] (Wheeler-Osgood)
Flow										
MGD	0.05	0.173	0.035	0.365	0.07	0.02	0.075	3.97	4.78	0.2825
% of loading to segment	0.52	1.81	0.37	3.83	0.73	0.21	0.79	41.62	50.12	NA
COD										
lb/day	NS	237.26	NS	NS	NS	NS	NS	314.97	637.62	672.88
% of loading to segment		19.94						26.47	53.59	NA
TSS										
lb/day	0.361	181.37	7.58	9.22	3.79	0.14	3.52	2,346.09	664.14	16.82[b] NA
PAHs										
HPAH										
lb/day	--	<0.00085	<0.00057	--	<0.00012	--	--	--	--	--
% of loading to segment		55.20	37.01		7.79					
LPAH										
lb/day	--	<0.44	--	--	--	--	--	<0.16	<0.016	0.036
% of loading to segment		71.43						25.97	2.60	NA
Metals										
Mercury										
lb/day	--	0.0005627	--	--	0.0000321	0.0000092	--	--	--	0.000267
% of loading to segment		93.16			5.31	1.53				NA
Zinc										
lb/day	0.0046	0.24	0.0057	0.11	0.018	0.0055	0.0056	1.4	1.2	0.19
% of loading to segment	0.15	8.04	0.19	3.68	0.60	0.18	0.19	46.83	40.14	NA
Lead										
lb/day	0.03	0.33	0.0065	0.017	0.00058	0.00058	0.0013	1.9	1.3	0.097
% of loading to segment	0.84	9.20	0.18	0.47	0.02	0.02	0.04	52.98	36.25	NA
Cadmium										
lb/day	0.0000417	0.0046892	0.0000504	0.0006088	0.0010508	0.0000167	0.0000626	0.113677	0.0039865	0.000589
% of loading to segment	0.03	3.78	0.05	0.49	0.85	0.01	0.05	91.53	3.21	NA
Nickel										
lb/day	--	--	0.0023352	--	0.0008757	0.005004	0.0006255	0.1324392	0.0797304	0.030629
% of loading to segment			1.06		0.40	2.26	0.28	59.92	36.08	NA
Copper										
lb/day	--	0.30	0.0096	--	--	0.0017	--	0.84	2.0	0.058
% of loading to segment		9.52	0.30			0.05		26.66	23.47	

[a] Contaminant loadings for Wheeler-Osgood Waterway are not summed with the other loadings for City Waterway for calculation of relative percentages. Contaminant transport between these two waterways is unknown, but is believed to be insignificant.

[b] COD loadings are believed to be over-estimated using analysis data of samples collected during high tide conditions.

-- = Not detected.

NA = Not applicable.

NS = Not sampled.

were also elevated, but not above the concentrations in sediment samples from an area immediately adjacent to storm drains CN-237 and CS-237.

A potential source of PAH metals to City Waterway Segment 1 is the Tacoma Spur site situated between South 21st and 23rd Streets to the north and south, and Dock and A Streets to the east and west. Release of PAH and metals results from two independent activities. Contaminated soil was discovered while conducting routine soil borings for the SR-705 highway project near the site of an old coal gasification plant that operated from 1884 to 1924. Soil and groundwater investigations by the Washington State Department of Transportation (WDOT) consultant, Hart-Crowser and Associates, indicated that soil and groundwater at this site was significantly contaminated with PAH. Some of the material removed from the site was designated as an extremely hazardous waste (pursuant to WDOE Dangerous Waste Regulations Chapter 173-303 WAC). The remaining, less contaminated material will be isolated in on-site storage facilities.

Approximately 200 batteries were also discovered under 1 ft of soil during the field investigation for the SR-705 highway project. WDOE estimated that the batteries were buried about 30 yr ago and had probably been used as switching signal batteries (Pierce, R., 2 August 1985, personal communication). Under WDOE direction, Burlington Northern Railroad and WDOT removed the batteries and sent them to the Chemical Securities Hazardous Waste disposal facility in Arlingon, Orgeon. Residual soil and groundwater contamination from the activities described above may continue to be sources of PAH and metals to City Waterway via groundwater transport.

The Tar Pits are located approximately 2,000 ft east of the City Waterway where a coal gasification plant operated from 1924 to 1950. Several ponds filled with liquid tar have been discovered at this site. The potential exists for PAH to migrate via groundwater to City Waterway. Source investigations are ongoing at the Tacoma Spur and Tar Pits sites.

Two additional sources of LPAH have been identified in City Waterway Segment 1. Petroleum product was collecting in storm drains near West Coast Grocery and discharging into City Waterway via CI-248. The source is unknown, but may be associated with the operation of a railroad roundhouse in this area. Oil/water separators were installed and the amount of product reaching the waterway was reduced. Petroleum product was also discovered on the west side of the waterway near 15th Street. The source was not determined, but WDOE identified four gasoline stations in the vicinity that are over 20 yr old (Pierce, R., 2 August 1985, personal communication). The WDOT installed portable air-stripping towers to remove the volatile compounds while dewatering this area for some construction work on the proposed freeway right-of-way. Further source investigations are recommended for the sources of petroleum product near 15th Street (east and west sides of City Waterway).

Sources of 2-methylphenol, phthalate esters, 4-methylphenol, N-nitrosodiphenylamine, aniline, and benzyl alcohol could not be identified using existing data.

3.4.3.1 Storm Drains CN-237, CS-237, and CI-230--

Storm drains CN-237 and CS-237, located at the head of City Waterway, discharge stormwater runoff generated in the Nalley Valley and south Tacoma. Additionally, some industries are authorized through issuance of NPDES permits to discharge noncontact process waters to these storm drains. Collectively, storm sewers CN-237 and CS-237 drain an area of approximately 8.2 mi^2. These drains account for 92 percent of the stormwater discharged to City Waterway Segment 1 and are the largest sources of zinc, lead, nickel, and organic matter to this segment. Combined loadings from these drains were estimated to be 2.6 lb/day of zinc, 3.2 lb/day of lead, and 0.212 lb/day of nickel. Organic loadings from these drains vary greatly. Average COD loadings from CN-237 and CS-237 were calculated to be 314 lb/day and 638 lb/day, respectively. The organic loading for CN-237 was calculated using an average flow of 3.97 MGD (over a 3-yr period) and an average COD concentration of 11 mg/L. The organic loading for CS-237 was calculated using an average flow of 4.78 MGD (over a 3-yr period) and an average COD concentration of 18.5 mg/L. Loading of LPAH was calculated to be less than 0.176 lb/day, and no HPAH were detected.

Storm drain CI-230, located on the west bank of City Waterway near the old 15th Street bridge, is the largest known source of HPAH, LPAH, and mercury. However, flow from this storm drain represents only approximately 1.8 percent of the total to City Waterway Segment 1. Contaminant loadings were estimated to be less than 0.00085 lb/day of HPAH, less than 0.44 lb/day of LPAH, and 0.00056 lb/day of mercury. After CN-237 and CS-237, CI-230 is the third largest source of zinc and lead. Contaminant loadings from CI-230 were estimated to be 0.24 lb/day of zinc and 0.33 lb/day of lead.

Several factors contribute to the contaminant loadings within the drainage areas of these storm drains. Urban runoff from areas including the I-5 freeway and commercial/industrial areas within drainages contribute metals, PAH, and organic matter to the storm sewer system. Cross-connections with the sanitary sewer system may be a source of organic matter and industrial wastes. Other potential contaminant sources include direct discharge or spillage into the storm sewers through catch basins, unauthorized commercial/industrial connections, and infiltration of contaminated groundwater. Remedial technologies which may be applicable to control contamination reaching City Waterway via CN-237, CS-237, and CI-230 include stormwater control technologies discussed in Section 2.3.5.

3.4.3.2 Martinac Shipbuilding--

Martinac Shipbuilding is located on the east bank of City Waterway, north of East 15th Street. Activities at this facility include building and repairing of ships. On the basis of a study conducted as part of the Commencement Bay Remedial Investigation, WDOE concluded that sediments near Martinac were substantially higher in priority contaminants zinc, and copper, and non-priority contaminants arsenic and beryllium relative to sediments in City Waterway and other waterways (Norton and Johnson 1984). Zinc concentrations in sediments collected off Martinac were up to eight times greater than those in sediments from mid-channel stations (Norton and Johnson 1984). Metals may be entering the waterway through the use of sandblasting grits and antifouling paints at this facility (Norton and

Johnson 1984). During the WDOE study (Norton and Johnson 1984), a coarse-grained black material, tentatively identified as sandblasting grit, was observed on the surface of grab samples and on portions of the beach at Martinac. "Tuf-Kut," the sandblasting material commonly used by Martinac, typically has a very high concentration of copper (1,300-5,000 ppm) and lower chromium and zinc concentrations (100 ppm and 75 ppm, respectively). Another potential source of metals from Martinac is antifouling paints, which have high concentrations of zinc and copper that act as toxic agents (Norton and Johnson 1984). These antifouling paints may enter the waterway by direct spillage during painting and repair of ships, and when old paint is sandblasted off ships. Remedial technologies which may be applicable to reduce amounts of metals entering City Waterway from the activities at Martinac Shipbuilding include:

- Discontinuation of direct discharge of sandblasting materials into City Waterway
- Improvements in product handling to prevent spillage of sandblasting materials and antifouling paints directly into City Waterway or within the surface water drainage of this waterway
- Improvements in ship repair procedures to minimize the amount of sandblasting grit (potentially containing old antifouling paint) that enters City Waterway (i.e., use of curtains or other containment devices around work area)
- Construction of surface drains along dry dock to collect wash water that may contain sandblasting grit and antifouling paints
- Treatment for contaminated surface and/or process water from the building and repair activities (e.g., sedimentation, filtration, coagulation/flocculation).

3.4.3.3 American Plating--

American Plating is an electroplating company located on the east bank at the head of City Waterway. A study conducted by the WDOE as part of the Commencement Bay Remedial Investigation indicated that sediment concentrations of nickel near American Plating were higher than those in adjacent sediments within City Waterway (Norton and Johnson 1984). Delineation of the relative importance of American Plating as a source of metals is complicated by the major metals loadings from storm drains CN-237 and CS-237, which also discharge at the head of City Waterway. Historically, metals may have entered City Waterway via the direct discharge of process wastewater. This discharge was discontinued in 1981 when American Plating connected to the sanitary sewer. For this reason, historical loading from American Plating is believed to be more significant than the present loading, if any. However, spills and unpermitted discharges from this facility are possible sources of recent or ongoing metals loadings to City Waterway. The WDOE Southwest Regional Office has documented numerous permit violations and spills around American Plating, and is currently in the process of collecting penalties issued against this company (Norton and Johnson 1984).

Remedial technologies which may be applicable to reduce quantities of metals entering City Waterway from American Plating include:

- Improvements in handling and storage of product and waste materials to minimize spillage and leakage (may include personnel training, inventory inspections)
- Development of an emergency spill plan to ensure expedient response and complete cleanup of spilled product and waste materials
- Construction of barriers, surface drains, or collection systems to prevent migration of spilled product and waste materials from property
- Treatment for contaminated surface water emanating from facilities, including floor drains (e.g., sedimentation, filtration, coagulation/flocculation)
- Soil sampling and, if necessary, removal
- Inspection of facility for non-permitted discharges to City Waterway
- Investigation of groundwater as a potential contaminant pathway to City Waterway from American Plating.

3.4.3.4 Unknown Sources--

For several of the priority contaminants in City Waterway Segment 1, confirmed sources have not been identified. Contaminants for which source identification was not possible with existing data are 2-methylphenol, 4-methylphenol, and phthalate esters, which are priority 2 contaminants; and dichlorobenzenes, N-nitrosodiphenylamine, aniline, and benzyl alcohol which are priority 3 contaminants. Some source information exists for HPAH and LPAH, but it appears unlikely that all sources and their respective loadings have been accounted for, since sampling data for these contaminants are limited and transport mechanisms are not well understood. Resampling of known sources is recommended to determine if PAH concentrations are increasing or decreasing. Additional source identification is also necessary for those contaminants with no available loading data.

3.4.4 Sediment Remedial Actions

Sediments within City Waterway Segment 1 have been assigned an environmental significance of 4 based on observed contamination levels, toxicity, and biological effects. This problem area is therefore recommended for consideration of remedial action to mitigate the environmental threat associated with the priority contaminants in the sediments. Remediation of the existing contamination is recommended only after the present sources of contaminants have been effectively controlled.

Options for management of contaminated sediments within City Waterway Segment 1 include dredging, in situ treatment/stabilization, and capping.

Capping may not be a feasible remedial option for management of contaminated sediments within City Segment 1 because present water depth is less than 10 ft below MLLW and facilities along the banks depend on waterway access by commercial and private vessels. In general, priority contaminants within City Waterway Segment 1 are either particle-bound or soluble and are likely to be most effectively removed by hydraulic dredging. Hydraulic dredging may be enhanced by the unconsolidated, slurry-like consistency of sediments within this segment. Currently, the only dredging project proposed in City Waterway is at the City Marina, but it is not certain whether this project will be pursued since the owner has not been willing to have chemical analyses performed on the sediments.

The volume of contaminated sediment within City Waterway Segment 1 is estimated to be 440,440 yd^3. This volume was estimated using a surface area of 42 ac, computed with a planimeter, and an average sediment depth of 6 to 7 ft. For the purpose of this preliminary volume calculation, contamination was assumed to extend through the soft sediment layer. If groundwater is determined to be a source of contaminants to City Waterway, lower sediment layers are also probably contaminated. Additional deep core sampling is necessary to determine the vertical extent of contamination.

3.4.5 Data Needs

Several data gaps exist for City Waterway Segment 1 that hinder the development and evaluation of specific source control and sediment remedial action alternatives. The vertical extent of contamination has not been defined and conclusive identification of potential sources has not been made. Data needs specific to City Waterway Segment 1 include

- Additional source investigation for priority contaminants listed in Section 3.2.3.4:

  Priority 2: 2-methylphenol, 4-methylphenol, phthalate esters
  Priority 3: N-nitrosodiphenylamine, aniline, benzyl alcohol

- Focused source investigations for the Tacoma Spur site; the Tar Pits site; city of Tacoma storm drains CN-237, CS-237, and CI-230; and West Coast Grocery

- Investigation of potential sources of petroleum product near 15th Street, both east and west sides of City Waterway

- The potential of the Wheeler-Osgood branch as a source of contaminants to City Waterway

- Cross section sediment sampling of City Waterway in the vicinity of 15th Street to define cross-waterway trends for PAH

- The vertical extent of contamination as determined by deep core sampling

- Sediment core dating to determine deposition dates of contaminants to delineate whether sources are ongoing or historical

- Determination of sedimentation rates in City Waterway Segment 1.

3.5 HYLEBOS WATERWAY SEGMENT 5

3.5.1 Physical Description

Segment 5 of Hylebos Waterway is located at the northwestern portion of the waterway, extending approximately from 2,250 ft to 5,800 ft from the mouth of the waterway. The width of the main channel measures between 600 ft and 1,000 ft in this segment, with a large intertidal area west of East 11th Street extending another 800 ft to the north. Recent subbottom profiling of Hylebos Waterway showed average mid-channel depths of 37-44 ft below MLLW in Segment 5. Cross sections in this segment indicate that depth varies from 28 ft below MLLW at the south bank to 36 ft below MLLW at mid-channel. Sediment accumulation is between 1 and 4 ft in this segment, with a pronounced accumulation of 4 ft along the south side of the waterway, adjacent to Occidental Chemical Corporation (Figure 36 of Raven Systems and Research 1984). Sediments within Hylebos Waterway are typically silty sands with an average composition of 64 percent fine-grained material and an average clay content of 20 percent. Past dredging activities in this segment include maintenance dredging by the U.S. Army Corps of Engineers in 1931, 1962, and 1972; and by the Occidental Chemical Corporation in 1967, 1968, and 1974.

Industrial facilities located along the banks of Hylebos Waterway Segment 5 include Tacoma Boatbuilding Company, PRI Northwest Inc., Occidental Chemical Corporation, and the Port of Tacoma industrial yard on the south bank. The north bank is bordered by a relatively steep, forested bluff above Marine View Drive (Figure 12). Occidental Chemical Corporation (HY-707, NPDES WA0037265) is the only permitted discharge to Hylebos Waterway Segment 5. Non-permitted discharges associated with Occidental Chemical Corporation include groundwater seeps (HY-083), seven steel pipes (HY-085), and the groundwater beneath Occidental Chemical Corporation. There are an additional 18 non-permitted surface water discharges to Segment 5 (Figure 13).

3.5.2 Extent of Contamination

Results of the Commencement Bay Nearshore/Tideflats Remedial Investigation indicate that polychorinated biphenyls (PCBs) are the priority 1 contaminant in Hylebos Waterway Segment 5. Priority 2 contaminants are hexachlorobutadiene, chlorinated benzenes, nickel, chlorinated ethenes, the pentachlorocyclopentane isomer, and lead. Priority 3 contaminants are mercury, HPAH, copper, zinc, LPAH, phenol, benzyl alcohol, and biphenyl. The area of concern is defined as the entire deep-water portion of the segment, excluding the intertidal area, based on biological and chemical analyses of sediment samples collected during this project at Stations HY-36, HY-38, HY-39, HY-40, HY-41, HY-42, HY-45, HY-46, and HY-47 (Figure 14); and on evalutation of historical sediment data. Analyses indicated elevated contaminant concentrations at the above stations within this segment and several abnormal biological conditions. Sediment bioassays indicated oyster larvae and amphipod toxicity. Analyses

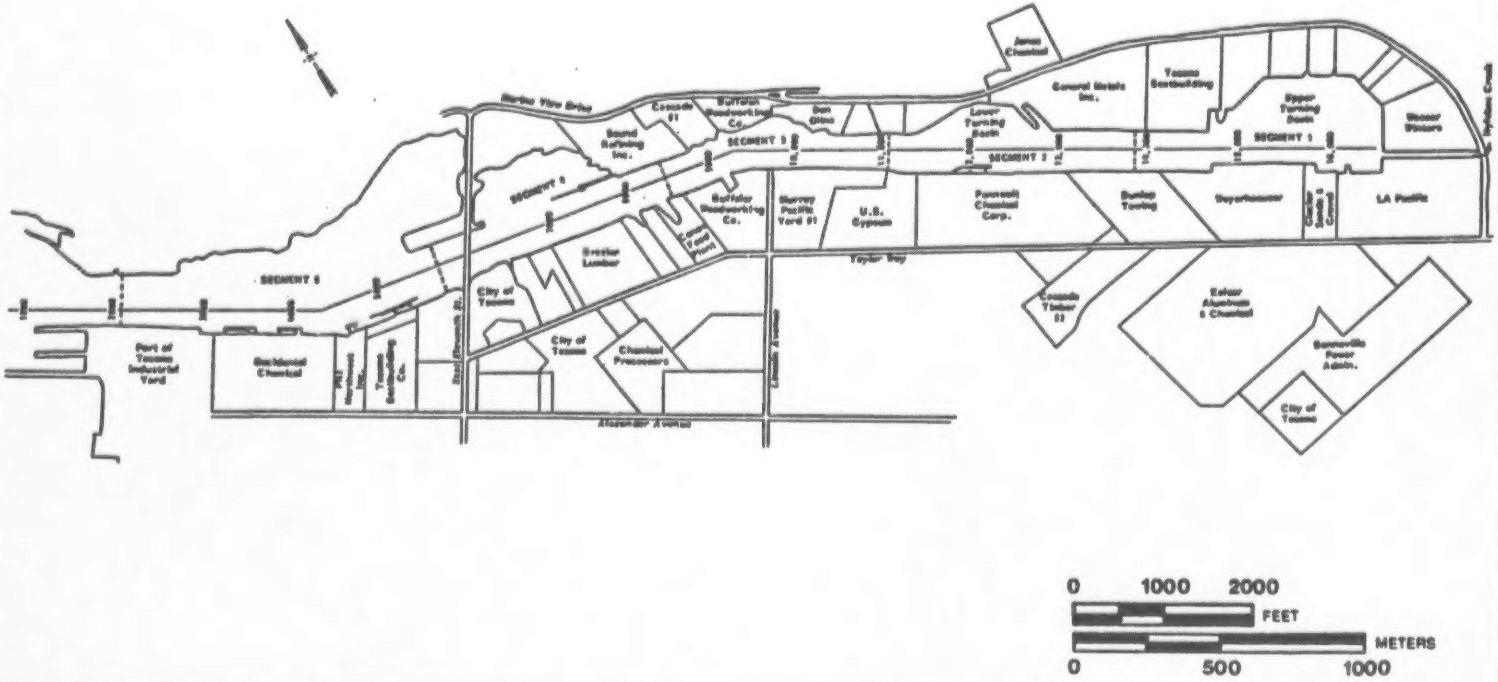

Harbor View Drive
Cascade 01
Buffelen Woodworking Co.
Don Oline
Jones Chemical
General Metals Inc.
Tacoma Boatbuilding
Upper Turning Basin
Wasser Winters
Hylebos Creek
Sound Refining Inc.
Lower Turning Basin
SEGMENT 1
SEGMENT 2
SEGMENT 3
SEGMENT 4
SEGMENT 5
Port of Tacoma Industrial Yard
Occidental Chemical
PRI Northwest Inc.
Tacoma Boatbuilding Co.
East Eleventh St.
City of Tacoma
Chemical Processors
Breslin Lumber
Buffelen Woodworking Co.
Murray Pacific Yard 01
U.S. Gypsum
Pennwalt Chemical Corp.
Dunlap Towing
Weyerhaeuser
LA Pacific
Taylor Way
Lincoln Avenue
Alexander Avenue
Cascade Timber 01
Kaiser Aluminum & Chemical
Bonneville Power Admin.
City of Tacoma
0
1000
2000
FEET
0
500
1000
METERS

Figure 12. Major industries surrounding Hylebos Waterway.

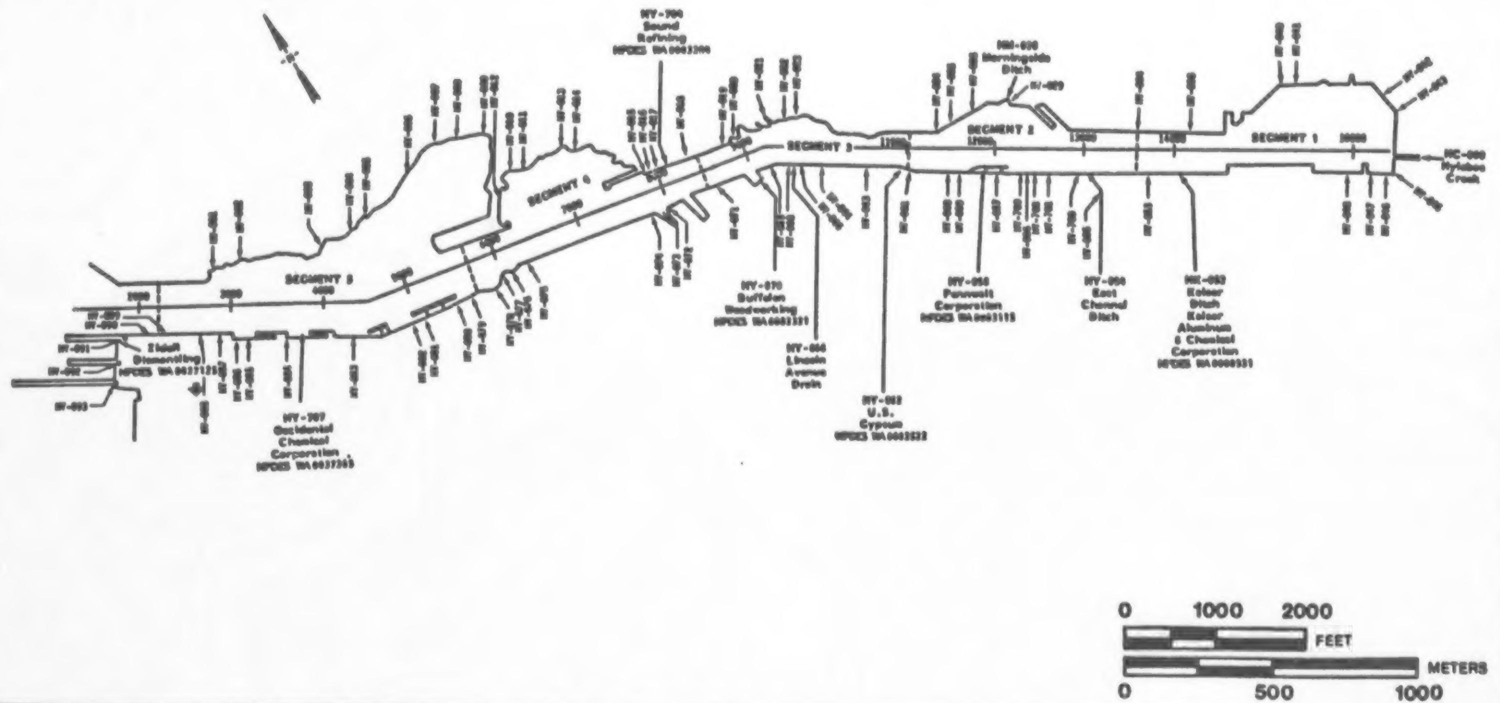
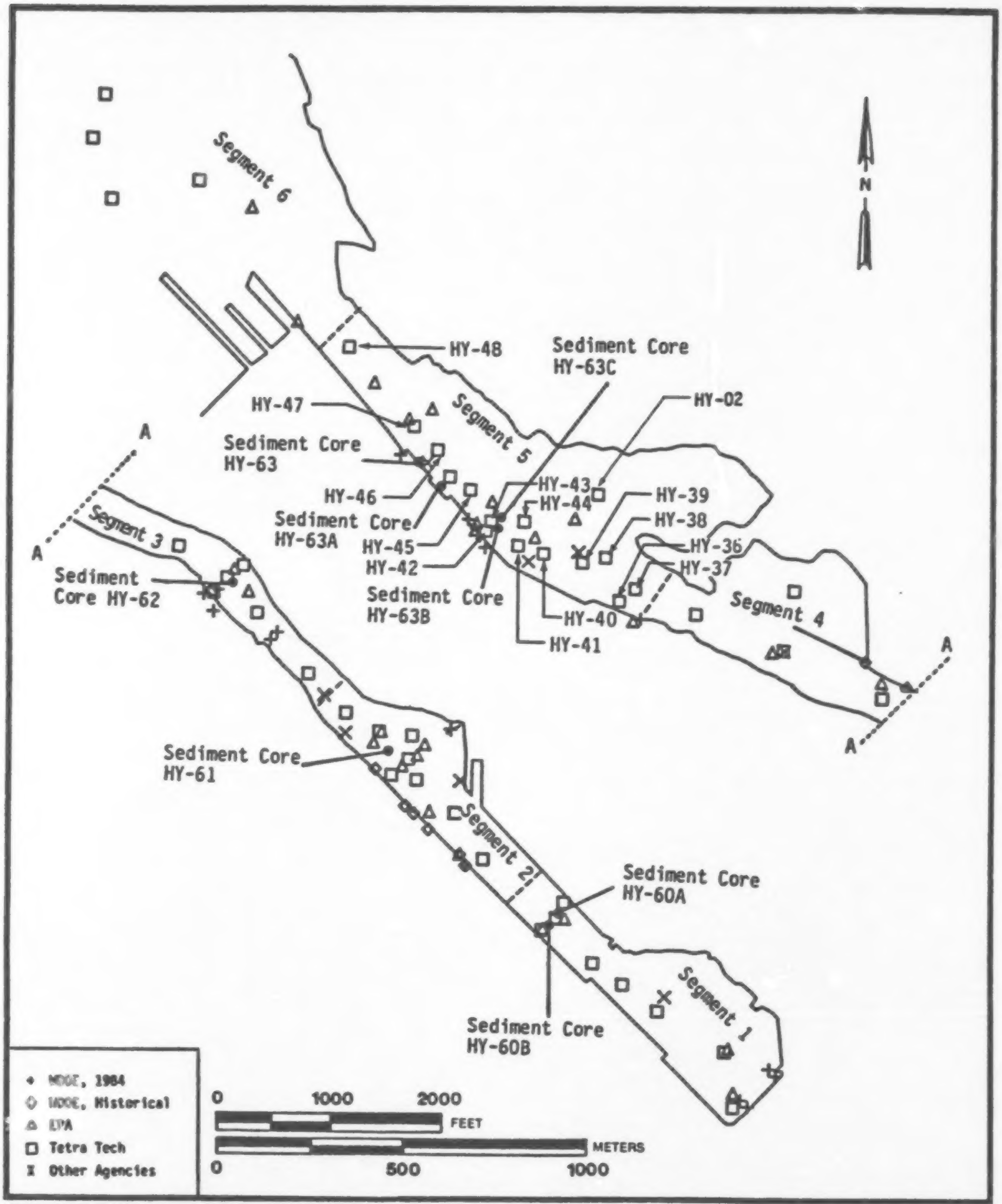

Sound
Refining
Zidell
Dismantling
Occidental
Chemical
Corporation
SEGMENT 5
SEGMENT 4
SEGMENT 3
SEGMENT 2
SEGMENT 1
Buffelen
Woodworking
Lincoln
Avenue
Drain
U.S.
Gypsum
Pennwalt
Corporation
East
Channel
Ditch
Morningside
Ditch
Kaiser
Ditch
Kaiser
Aluminum
& Chemical
Corporation
Hylebos
Creek
0
1000
2000
FEET
METERS
0
500
1000

Figure 13. NPDES-permitted and non-permitted discharges to Hylebos Waterway.



N
Segment 6
Segment 5
Segment 4
Segment 3
Segment 2
Segment 1
A
A
A
A
HY-48
Sediment Core
HY-63C
HY-02
HY-47
Sediment Core
HY-63
HY-46
Sediment Core
HY-63A
HY-45
HY-42
HY-43
HY-44
HY-39
HY-38
HY-36
HY-37
HY-40
HY-41
Sediment Core
HY-63B
Sediment
Core HY-62
Sediment Core
HY-61
Sediment Core
HY-60A
Sediment Core
HY-60B
WDOE, 1984
WDOE, Historical
EPA
Tetra Tech
Other Agencies
0
1000
2000
FEET
METERS
0
500
1000

Figure 14. Surficial sediment and sediment core sampling station locations from all Hylebos Waterway Segment 5 studies in the Commencement Bay Remedial Investigation database.

of fish caught in Hylebos Waterway indicated liver lesions and significant accumulation of mercury, phthalates, and PCBs in muscle tissues.

A high priority problem area was identified in Hylebos Waterway Segment 5, west of the 11th Street Bridge. While cross-channel sampling was limited, existing data showed sediments from the southern side of the waterway to be more contaminated than those from the middle or north side. A single sample from the large shallow area on the north shore (HY-02) indicated that chemicals in this area were not significantly elevated above Puget Sound Reference conditions. Anomalously low elevations above reference for all chemicals were also measured at Station HY-44, located within the problem area. The simplest explanation is that this station contained relict sediments either dumped at the site in a dredging operation or exposed by ship scour. Concentrations of the majority of the chemicals measured in sediments along the south shore were not greatly elevated above reference conditions, although selected chlorinated compounds were present in the highest concentrations observed throughout Commencement Bay. Their spatial distributions were not as simple as might have been expected if all compounds had originated from a single source. Intertidal and shallow subtidal sediments along the southern shore about 3,000 ft from the waterway mouth were highly contaminated with chlorinated ethenes. The concentrations of these compounds sometimes exceeded AET values by several orders of magnitude. These very high contaminant levels were restricted to the nearshore area, and declined rapidly with distance offshore and alongshore. Chlorinated butadiene concentrations exhibited the strongest single gradient, maximizing at Stations HY-43, HY-46, and HY-47 (all contiguous nearshore stations on the south side of the channel). Only concentrations of hexachlorobutadiene exceeded AET in this area. Concentrations of a tentatively identified pentachlorocyclopentane isomer and many of the chlorinated benzenes were highly elevated (above AET) at Station HY-46 and also at Station HY-36, near the 11th Street Bridge. PAH concentrations were also elevated near the 11th Street Bridge.

3.5.3 Contaminant Sources

Occidental Chemical Corporation is the only confirmed source of chlorinated hydrocarbons (chlorinated ethenes, butadienes, and benzenes) and mercury to Hylebos Waterway Segment 5. Contaminant loadings from the discharges associated with Occidental Chemical Corporation are presented in Table 5. Groundwater beneath Occidental Chemical Corporation is the major transport mechanism by which chlorinated ethenes enter the waterway, while the principal known route for chlorinated benzenes and butadienes has been the main plant outfall (HY-707). The only confirmed route of mercury to Segment 5 is via discharge HY-085. However, it is likely that observed mercury contamination in the sediment is from other unknown sources.

The sources of PCBs are unknown. It is also unknown whether the contaminant levels observed in surficial sediments are due to historical or recent deposition. There are several possible explanations for elevated concentrations of PCBs in surficial sediments, including exposure of historical contamination during dredging activities and by ship scouring, dispersion of PCB-contaminated sediments during dredging activities, and ongoing or recent discharges. Ongoing or recent discharges were not considered a major source since PCBs were not detected in discharges to this segment. In addition, chemical analyses of these sediment PCBs indicated they were

TABLE 5. CONTAMINANT LOADINGS AND RELATIVE PERCENTAGES FOR HYLEBOS WATERWAY SEGMENT 5

Contaminant	HY-083	Discharge HY-085	HY-707	Groundwater Beneath Occidental
PCB[a]	ND	ND	ND	
loading, lb/day				
% of loading to segment				
% of loading to waterway				
Chlorinated Hydrocarbons				
Butadienes[a]	ND			
loading, lb/day		0.00002	0.026	
% of loading to segment		0.08	99.92	
% of loading to waterway		0.08	99.58	
Benzenes[a]				
loading, lb/day	ND	<0.00006	0.039	
% of loading to segment		0.15	99.85	
% of loading to waterway		<0.01	6.01	
Ethenes[a]				
loading, lb/day	<0.00015	0.0016	0.65	5.9
% of loading to segment	<.01	0.02	9.92	90.05
% of loading to waterway	<.01	0.02	8.16	74.11
Metals				
Mercury[a]			ND	
loading, lb/day		0.000029		
% of loading to segment		100		
% of loading to waterway		<0.01		

[a] priority contaminant.

weathered, either in the terrestrial or the marine environment over a period of years. Sources of pentachlorocyclopentane isomer, phenol, benzyl alcohol, and biphenyl remain unknown as well.

3.5.3.1 Occidental Chemical Corporation--

Occidental Chemical Corporation is an ongoing source of chlorinated hydrocarbons (benzenes, butadienes, and ethenes) and mercury to Hylebos Waterway Segment 5. Current discharges associated with Occidental Chemical Corporation include the main plant outfall HY-707, surface drain HY-085, groundwter seep HY-083 and the groundwater beneath the plant site (area 2 and area 3). Occidental Chemical Corporation is the largest known source of chlorinated ethenes and butadienes to Hylebos Waterway. A total loading of approximately 6.6 lb/day of tri- and tetrachloroethene has been discharged to Hylebos Waterway from Occidental Chemical Corporation, representing over 82 percent of the total loading to the waterway. Groundwater contributes the majority of the loading: 5.9 lb/day from both areas 2 and 3. An estimated 0.02602 lb/day of chlorinated butadienes are discharged to Segment 5 via the main plant outfall (HY-707) and surface water (HY-085), which represent the total known loading to Segment 5, and nearly 100 percent of the known loading to Hylebos Waterway. Of the four confirmed sources of chlorinated benzenes to Hylebos Waterway, Occidental Chemical Corporation is ranked third in significance. An estimated 0.03906 lb/day of chlorinated benzenes is discharged to Segment 5 from Occidental Chemical Corporation via the main plant outfall (HY-707) and surface water (HY-085). This loading represents 100 percent of the known loading to Segment 5, but only 6 percent of the known loading to the entire waterway. Mercury has only been detected in one discharge associated with Occidental Chemical Corporation. The estimated loading of 0.000029 lb/day of mercury is discharged to Hylebos Waterway Segment 5 via HY-085. This loading represents 100 percent of the known loading to Segment 5, but only 0.01 percent of the known loading to the waterway.

Chlorinated hydrocarbons, particularly chlorinated ethenes, have been released into the environment either as a product or a byproduct of past and present manufacturing practices. At Occidental Chemical Corporation two independent activities identified as potential sources of chlorinated hydrocarbons are: 1) the production of chlorine and caustic soda by electrolysis of sodium chloride brine, and 2) the operation of a solvents production facility. There has been historical practices of direct discharge of wastes from these two operations. Contamination of Hylebos Waterway occurring via groundwater is largely the result of solvent plant wastes that were disposed on-site during the years from 1947 to 1973 when Occidental Chemical Corporation operated their solvents plant. Contaminants were leaching into groundwater and subsequently into Hylebos Waterway from unlined waste lagoons and buried wastes. Waste lagoons were removed from service about 1974. Occidental Chemical Corporation hired consulting firms Walker Wells, Inc., and Hart-Crower and Associates to assess the extent of chlorinated organic contamination in the soil and groundwater beneath the plant site. Sample analyses revealed total chlorinated organics concentrations up to 20,000 ug/kg in soils and up to 700 ug/L in groundwater from the Occidental Chemical Corporation property. As a result of these investigations, WDOE ordered Occidental Chemical Corporation to remove the most contaminted soils (exceeding 150 mg/kg) and to cap with an impermeable material those areas that exceeded concentrations of 15 mg/kg (Docket No. DE81-153). These actions have been completed, and groundwater wells were installed to monitor contaminant concentrations after the removal of contaminated soils. Occidental Chemical Corporation is required to monitor groundwater quality quarterly. No improvement in groundwater quality has been observed since contaminated soils were removed in 1981 as evidenced by the data submitted by Occidental Chemical Corporation to WDOE (Figure 15).

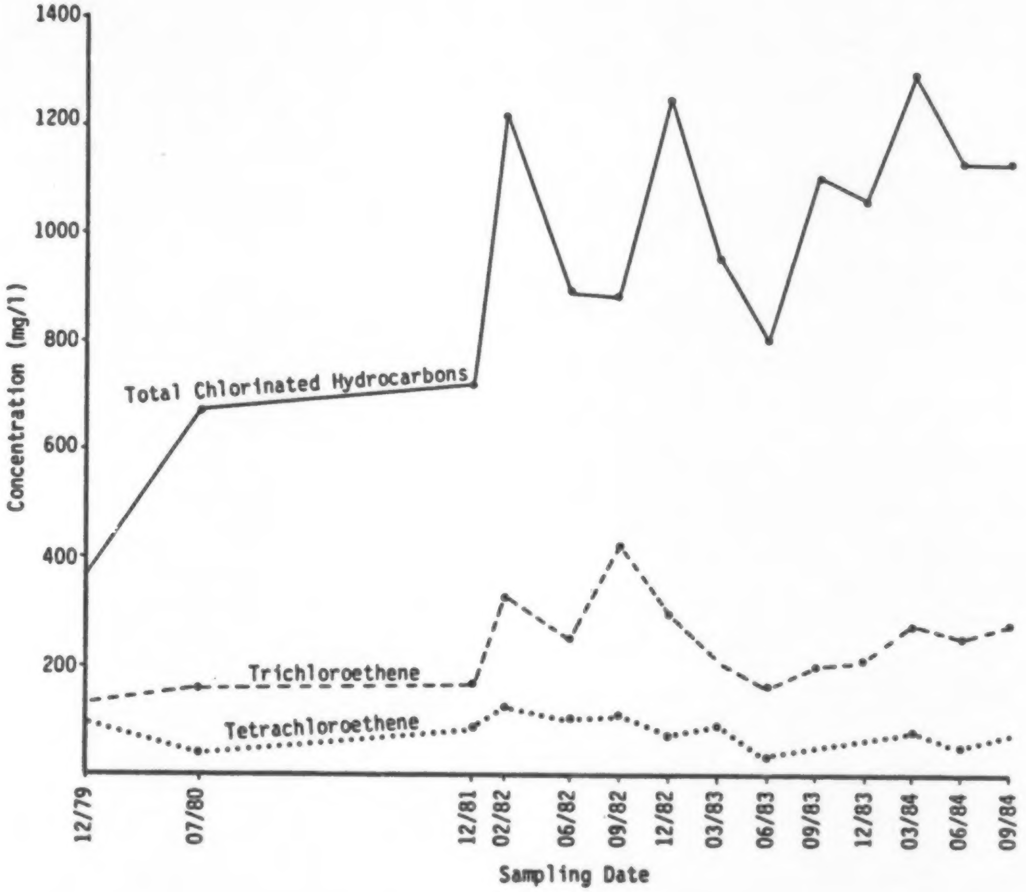
Waste sludges removed from these lagoons during routine maintenance were disposed in several locations within the Commencement Bay area. The WDOE confirmed the locations of four such disposal areas and suspects a fifth location (Pierce, R., 13 May 1985, personal communication). Occidental Chemical Corporation voluntarily installed monitoring wells at three of the confirmed disposal sites and sampled the groundwater on two separate occasions. The extent of groundwater monitoring required at the fourth confirmed site is currently being negotiated between WDOE and Occidental Chemical Corporation (Pierce 1985).

Occidental Chemical Corporation is planning to dredge Hylebos Waterway in the vicinity of their dock. The WDOE reviewed and approved the sampling and analysis plan on December 5, 1984, and sediments were sampled on December 10, 1984, while WDOE inspected Occidental's sampling and analysis procedures. A turn-around time of 6 wk was scheduled for lab analyses, but as of April 22, 1985, the WDOE had not received the sediment data from Occidental Chemical Corporation. Previous sediment samples analyzed in 1983 showed high concentrations of chlorinated organic compounds (particularly chlorinated ethenes).

WDOE believes a significant quantity of organic chemicals may be leaving Occidental Chemical Corporation adsorbed onto solids in the effluent waste stream but undetected due to high dilution. To quantify this amount, if present, the WDOE is considering requesting Occidental Chemical Corporation and other chemical manufacturers to perform organic chemical analyses on the filtered solids from their effluents (Eaton, T., 10 May 1985 personal communication).

Contaminants enter Hylebos Waterway and the surrounding environment via direct discharge of process wastewaters, groundwater, and potentially surface water runoff from Occidental Chemical Corporation. Control of these contaminant routes may require implementation of a remedial plan that integrates several technologies. Although discussion of specific in-plant control technologies is not within the scope of this task, contaminant loadings from process effluents are significant and must be addressed in a source control plan. The main plant outfall is the largest source of chlorinated butadienes and the third largest source of chlorinated ethenes to Hylebos Waterway.

There has been no documented release of contaminated surface water from the Occidental Chemical Corporation; however, the potential exists for shallow contaminated groundwater to infiltrate storm sewer lines and enter Hylebos Waterway via these outfalls. Since the most highly contaminated soils have been removed and most of the site paved, surface water runoff from Occidental Chemical Corporation is not expected to be contaminated. Additional investigation is necessary to determine whether surface water is a transport route for contaminants from Occidental Chemical Corporation.



NOTE: DATA SHOWN ARE FROM WELL NO.4, LOCATED IN AREA 2. SAMPLES WERE COLLECTED AT SCREENED DEPTHS OF 45 FT. SAMPLE COLLECTED 12/79 WAS ANALYZED BY CAN TEST. ALL OTHER SAMPLES WERE ANALYZED BY OCCIDENTAL CHEMICAL CORPORATION.

Figure 15. Concentration of chlorinated compounds in groundwater beneath Occidental Chemical Corporation.

If confirmed, evaluation and implementation of surface water controls may be necessary to reduce the contaminant loadings from this route.

Groundwater beneath Occidental Chemical Corporation is the largest source of chlorinated ethenes to Hylebos Waterway. Contamination of groundwater may be a result of one or more of the following: leaching from historically contaminated soils, leaching from buried waste sludges, exfiltration from buried waste and process lines, leaking storage tanks, and chemical spills. Applicable remedial technologies to mitigate groundwater contamination at Occidental Chemical Corporation include

- Excavation of remaining contaminated soils and replacement with clean material, if necessary
- Capping, covering, or paving of remaining contaminated areas to reduce vertical migration of contaminants
- Inspection of underground lines and tanks (if applicable) for cracks, breaks, and leaking connections. Repair, if necessary
- Groundwater controls, see Section 2.4.

The above technologies vary considerably in the extent to which they control groundwater contamination. For maximum mitigation, groundwater pumping and treatment in conjuction with contaminated soil removal is necessary. Effectiveness of the previous groundwater and contaminated soils remedial actions should be evaluated prior to implementation of new control technologies. Since the contaminants of major concern are volatile organics, air stripping, with appropriate air pollution controls, may prove to be the most effective technology for groundwater contamination at Occidental Chemical Corporation.

3.5.3.2 Unknown Sources--

For several of the priority contaminants in Hylebos Waterway Segment 5, confirmation of sources is not possible with existing data. Contaminants for which additional source identification is needed include PCBs, pentachlorocyclopentane isomer, lead, HPAH, copper, zinc, LPAH, phenol, benzyl alcohol, and biphenyl. Additional discharge monitoring for these specific contaminants is necessary to identify the sources. Mercury has been detected in a discharge from Occidental Chemical Corporation (HY-085). However, this discharge is approximately 1,000 ft closer to the mouth of the waterway than is the "hot spot" and is not likely to be the only source. Therefore, additional source identification is required for mercury within Segment 5 and other segments of Hylebos Waterway.

3.5.4 Sediment Remedial Actions

Sediments in Hylebos Waterway Segment 5 have been assigned an environmental significance ranking of 4 based on observed contamination levels, toxicity, and biological effects. Therefore, it is recommended that this area be considered for remedial action to reduce the environmental and public health threat associated with the priority contaminants in the sediments. Remediation of the existing contaminated sediments should be implemented only after the present sources of all priority contaminants have been effectively controlled.

As part of a dredging permit application process, Occidental Chemical Corporation recently sampled sediments immediately off their dock. It is likely that sediments close to the Occidental Chemical Corporation outfall will be classified as a dangerous waste under the Washington State Dangerous Waste regulations, and if dredged, will require disposal at a RCRA-approved site (e.g., Chem Securities in Arlington OR). It should be noted that dredging in this area may expose buried sediments that are more contaminated than are the surficial sediments.

Options for management of contaminated sediments within Hylebos Waterway Segment 5 include capping, in situ treatment/stabilization, and dredging. Capping probably is not applicable as a remedial technology within Hylebos Waterway because frequent dredging will be necessary to allow clearance for deep draft ships. Selection of the most appropriate dredging method is complicated by the combination of very high concentrations of volatile organic compounds (greater than 350,000 ppb of chlorinated ethenes) and PCBs, which are sediment-bound contaminants. The U.S. Army Corps of Engineers generally recommends mechanical dredging for the former group of contaminants and hydraulic dredging for the latter group. The volume of contaminated sediments within Hylebos Waterway Segment 5 is estimated to be 198,440 yd^3. This volume was estimated using a surface area of 41 ac, computed with a planimeter, and an average sediment depth of 3 ft, estimated from recent subbottom profiles (Raven Systems and Research 1984). For the purpose of this preliminary volume calculation, contamination was assumed to extend through the soft sediment layer. Contamination probably extends into the harder underlying sediment layers from the migration of contaminants in groundwater. Additional deep core sampling is necessary to determine the actual vertical extent of contamination.

3.5.5 Data Needs

Several data needs were identified that hinder the development or evaluation of potential remedial alternatives for the problem area in Hylebos Waterway Segment 5. Data gaps are associated with either the non-definitive boundaries of the area problem or with the inconclusive identification of potential sources. Specific data needs include

- Additional source identification of priority contaminants listed in Section 3.5.3.2:

Priority 1 - PCBs
Priority 2 - Hexachlorobutadiene, chlorinated benzenes, chlorinated ethenes, pentachlorocyclopentane isomer, lead
Priority 3 - Mercury, HPAH, copper, zinc, LPAH, phenol, benzyl alcohol, biphenyl

- More precise definition of vertical extent of contaminant by deep core sampling of sediments

- Vertical distribution of PCBs and the extent to which sediment concentrations are due to current discharges, if any. Information that may be useful in this determination includes sedimentation rates, dating of deep sediment cores, and additional source investigation

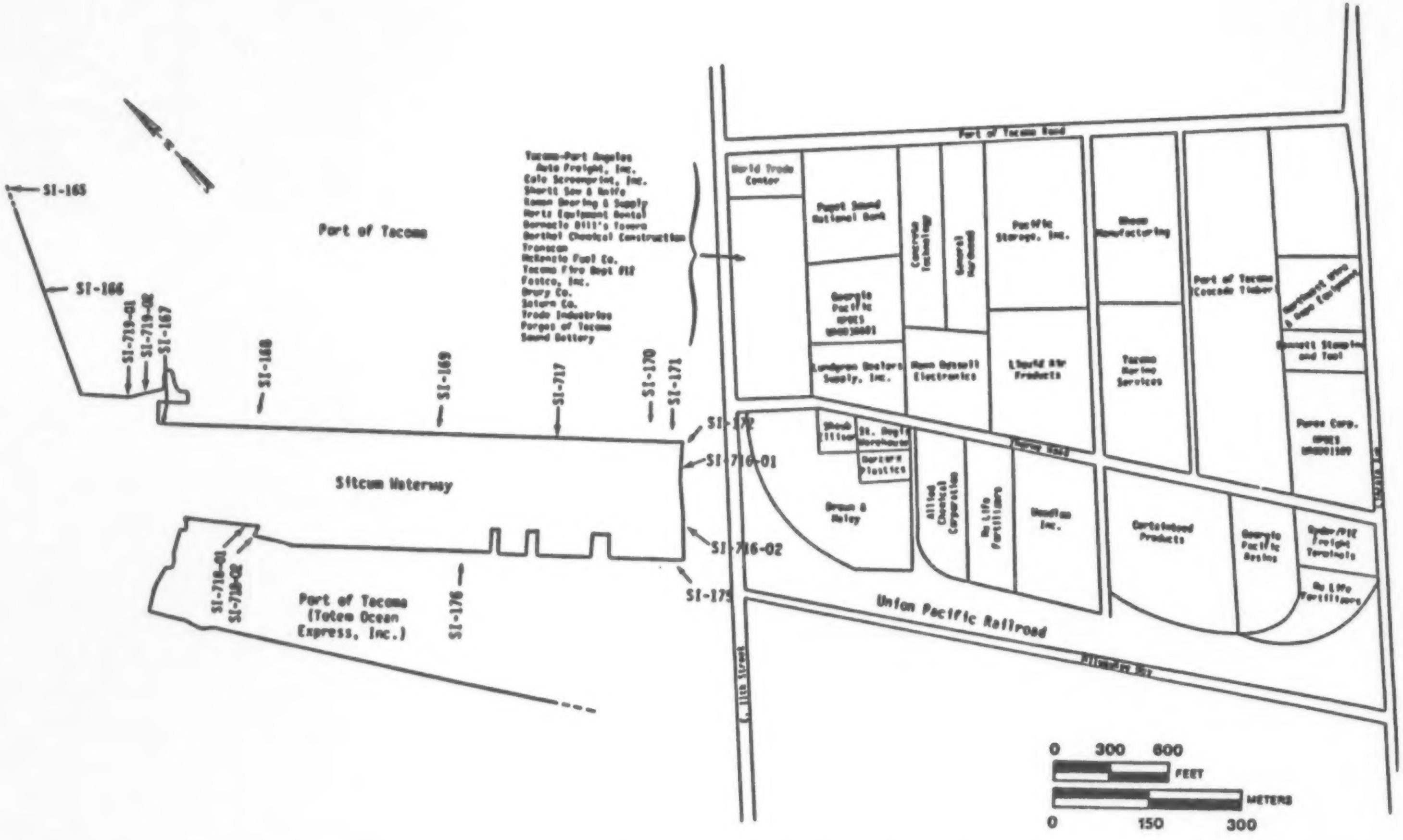
- A survey to identify all potential past and current sources of PCBs, including identification of electrical equipment containing PCB oil.

3.6 SITCUM WATERWAY

3.6.1 Physical Description

Sitcum Waterway is situated between Blair Waterway to the north and Milwaukee Waterway to the south. The Port of Tacoma owns the land along the north and the south shores (Figure 16). The south shore is leased to Sealand for storage, shipping, and receiving facilities. The Port's Terminal 7 is located along the north shore and is equipped with facilities for container handling and bulk unloading of alumina, various ores, and ore concentrates (primarily zinc, copper, and lead). The pier at Terminal 7 is 2,700 ft long with four berths (A, B, C, and D). Both properties are paved and accessible by railroad. There are no permitted discharges to Sitcum Waterway and 17 non-permitted discharges. There are 10 storm drains (SI-172, SI-175, SI-176, SI-716-01, SI-716-02, SI-717, SI-718-01, SI-718-02, SI-719-01, and SI-719-02); and various sized concrete outfalls (SI-165, SI-166, SI-167, SI-168, SI-169, SI-170 and SI-171) (Figure 17). SI-176 also serves as an emergency sanitary sewer bypass.

Nine dredging activities since 1946 have shaped the Sitcum Waterway into its present configuration. The waterway is approximately 3,200 ft in length with an average width of 600 ft. Initial dredging of Sitcum Waterway occurred in 1946 and routine waterway dredging was performed again in 1956 and 1968. Terminal 7 was dredged in 1961, 1966, 1973 and 1982. The West Sitcum Terminal (Sealand) was dredged in 1979 and 1983. Currently, water depths at Terminal 7 range from 35 ft below MLLW in berth A to 50 ft below MLLW in berth D (Norton and Johnson 1985b). The main channel is 40 ft below MLLW or deeper (Raven Systems and Research 1984). Sediments are typically 70 percent fine-grained material, with a clay content of nearly 20 percent. Recent profiling of the Sitcum Waterway indicated little recent sedimentation of solids in the channel, except outside the mouth where deposition of soft mud ranged from 1 to 6 ft (Raven Systems and Research 1984).



SI-165
SI-166
SI-719-01
SI-719-02
SI-167
SI-168
SI-169
SI-717
SI-170
SI-171
SI-172
SI-716-01
SI-716-02
SI-175
SI-176
SI-718-01
SI-718-02
Port of Tacoma
Sitcum Waterway
Port of Tacoma (Totem Ocean Express, Inc.)
Tacoma-Port Angeles Auto Freight, Inc.
Cole Screenprint, Inc.
Sound Battery
Forges of Tacoma
Trade Industries
Saturn Co.
Drury Co.
McKenzie Fuel Co.
Transcon
World Trade Center
Puget Sound National Bank
Georgia Pacific NPDES
Lundgren Dealers Supply, Inc.
Concrete Technology
Electronics
Pacific Storage, Inc.
Liquid Air Products
Manufacturing
Services
Port of Tacoma (Cascade Timber)
and Tool
Port of Tacoma Road
St. Regis Warehouse
Plastics
Brown & Haley
Allied Chemical Corporation
Nu Life Fertilizers
Inc.
Products
Georgia Pacific Resins
Freight Terminals
Nu Life Fertilizers
Union Pacific Railroad
E. 11th Street
0 300 600 FEET
0 150 300 METERS

Figure 16. Discharges to and industries surrounding Sitcum Waterway.

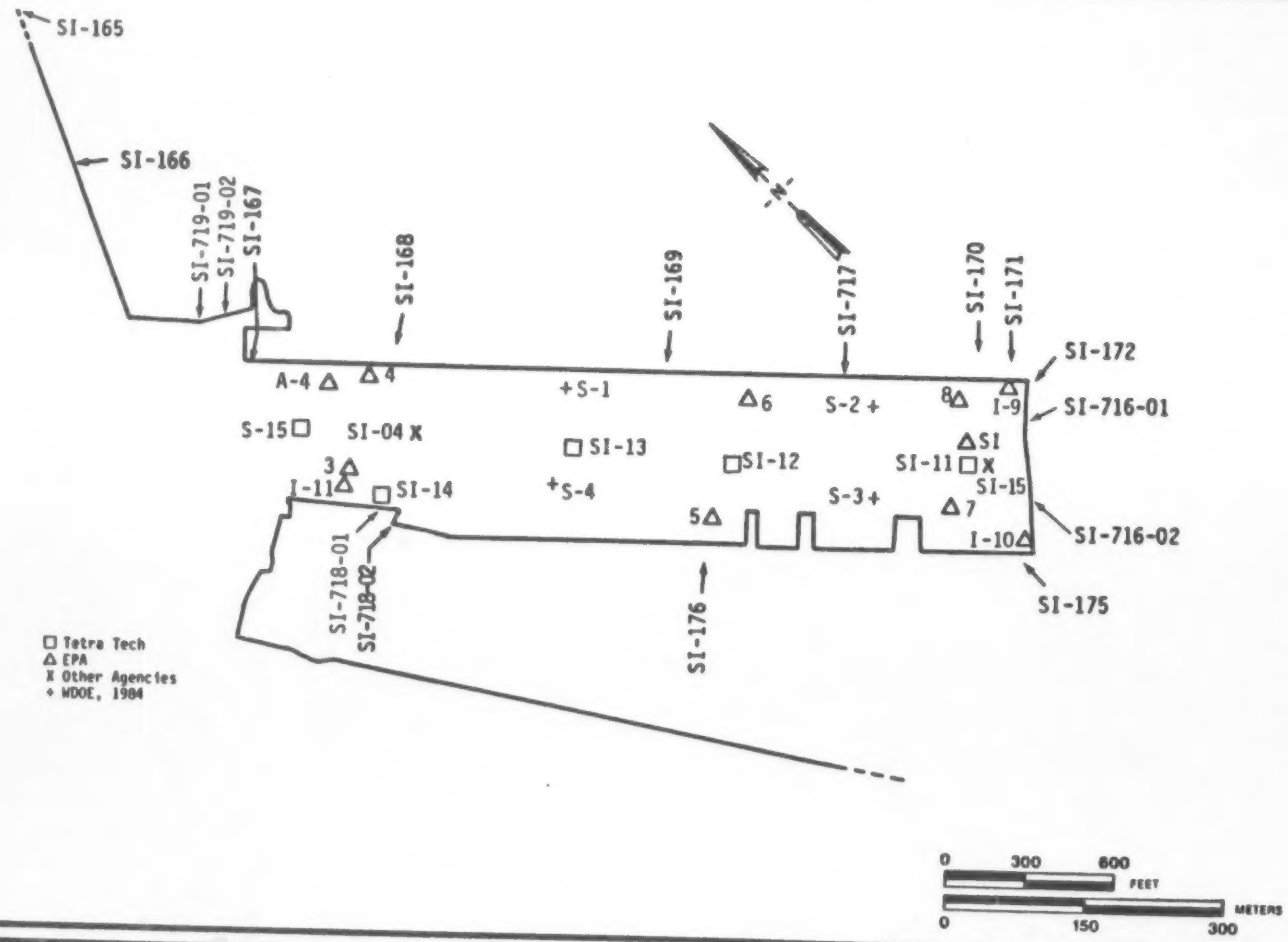

SI-165
SI-166
SI-719-01
SI-719-02
SI-167
SI-168
SI-169
SI-717
N
SI-170
SI-171
SI-172
SI-716-01
SI-716-02
SI-175
SI-176
SI-718-01
SI-718-02
A-4
4
+S-1
6
S-2 +
8
I-9
SI
SI-11
X
SI-15
7
I-10
S-3 +
5
SI-12
SI-13
+S-4
SI-14
3
I-11
S-15
SI-04 X
□ Tetra Tech
△ EPA
X Other Agencies
+ WDOE, 1984
0
300
600
FEET
0
150
300
METERS

Figure 17. Surficial sediment and sediment core sampling station locations from all studies in Sitcum Waterway.

3.6.2 Extent of Contamination

Results of the Commencement Bay Nearshore/Tideflats Remedial Investigation indicate that arsenic, copper, zinc, and lead are priority 2 contaminants and that N-nitrosodiphenylamine, dibenzofuran, 1-methyl(2-methylethyl)benzene, diterpenoid hydrocarbons, LPAH, and HPAH are priority 3 contaminants. The area of concern is defined as the entire waterway, based on chemical and biological analyses of sediment samples collected during the project at Stations SI-11, SI-12, SI-13, SI-14, and SI-15 (Figure 17) and an evaluation of historical sediment data. Chemical analyses indicated elevated contaminant concentrations at all stations, and sediment bioassays indicated amphipod toxicity. Bioaccumulation of PCBs in fish muscle tissue and a high prevalence of hepatic neoplasms in English sole were major factors that increased the ranking of this problem area. Sitcum Waterway sediments differed from those in neighboring waterways primarily in the much higher EAR for most of the metals.

Based on the most recent midchannel samples collected by Tetra Tech, metals were present at high EAR at the head of the waterway and decreased in concentration toward the mouth. However, consideration of historical data reveals more patchy distribution of metals, with no apparent longitudinal gradient. This may be a result of recent dredging activities at Terminal 7 and Sealand, or the locations of known sources on both sides and at the head of the waterway. The concentrations of several metals in both data sets exceed AET (i.e., arsenic, copper, lead and zinc). Most of the organic compounds were present at low EAR compared with those in many other areas of Commencement Bay. Both the LPAH and HPAH had two maxima, one near the head of the waterway in conjunction with the high EAR for metals, and one near the mouth at Station SI-14. Recent dredging by the Port of Tacoma off the Sealand facility, located at the mouth of Sitcum Waterway, removed approximately 11 ft of sediment. Station SI-14 was located within the area disturbed by this dredging activity. PCBs were detected in Sitcum Waterway sediments, but the concentrations did not exceed the 80th percentile value for all Commencement Bay sediments.

3.6.3 Contaminant Sources

Metals are entering Sitcum Waterway by two major routes: ore spillage at the Port of Tacoma's Terminal 7 and storm drains (particularly SI-172, SI-176, and SI-717). Metals loadings from storm drains that discharge to Sitcum Waterway and their respective percentages compared to total loadings are presented in Table 6.

Metals loadings from storm drain SI-172 may be underestimated relative to those from other storm drains in Sitcum Waterway. Loadings from SI-172 were calculated by averaging data collected on several occasions, including during dry weather, while the loadings for the other storm drains were calculated using data from a single storm event. After evaluating data collected from 10 storm drains during a single storm event on June 26, 1984, the WDOE concluded that SI-172 contributed 80 to 90 percent of the total metals loadings (Norton and Johnson 1985b). This percent differs greatly from the loading of 36 percent calculated using all available data. For the purposes of this report, metals sources will be prioritized on relative importance based on all available data. Ore spillage from Terminal 7 is

TABLE 6. CONTAMINANT LOADINGS AND RELATIVE PERCENTAGES FOR SITCUM WATERWAY

Contaminant	Discharge							
	SI-172	SI-175	SI-176	SI-716	SI-717	SI-718	SI-719	Total
Metals								
Zinc[a]								
loading, lb/day	1.23	0.20	1.75	0.029	1.23	0.03	0.11	4.579
% total to waterway	26.86	4.37	38.22	0.63	26.86	0.66	2.40	
Lead[a]								
loading, lb/day	0.36	0.022	1.56	0.028	0.90	0.0057	0.084	2.9597
% total to waterway	12.16	0.74	52.71	0.95	30.41	0.19	2.84	
Arsenic[a]								
loading, lb/day	1.8	0.0040	0.068	0.0035	0.056	0.0098	0.0024	1.9437
% total to waterway	92.61	0.21	3.50	0.18	2.88	0.50	0.12	
Copper[a]								
loading, lb/day	0.57	0.03	0.38	0.018	0.36	0.0069	0.027	1.3919
% total to waterway	40.95	2.16	27.30	1.29	25.86	0.50	1.94	
Total								
loading, lb/day	3.96	0.256	3.758	0.0785	2.546	0.0524	0.2234	10.8743
% total to waterway, %	36.42	2.35	34.56	0.72	23.41	0.48	2.05	

[a] Priority contaminant.

a major source of metals to the Sitcum Waterway, but the relative importance of this source has not been quantified. In order of significance, discharges of arsenic from storm drains are as follows: SI-172, SI-176, SI-717, SI-718, SI-175, SI-716, and SI-719. In order of significance, discharges of other metals (copper, lead, and zinc combined) are as follows: SI-176, SI-172, SI-717, SI-716, SI-175, SI-719, and SI-718. In general, the overall priority for source control is as follows: Port of Tacoma Terminal 7, SI-172, SI-176, and SI-717. Terminal 7 should be given top priority because it is believed to be a major source that does not need additional source identification efforts. Identification and control of contaminant sources to the storm drainage system, and subsequently to Sitcum Waterway, will require additional source identification and longer implementation time. No sources of aromatic hydrocarbons and dibenzofuran could be identified.

3.6.3.1 Port of Tacoma Ore Docks--

Ore spillage from the Port of Tacoma's Terminal 7 is considered to be a potentially large source of metals to Sitcum Waterway. Although no quantitative loadings have been calculated, it is estimated that spillage of approximately 10 lb of zinc ore would exceed the combined metals loading from all storm drains in Sitcum Waterway. As part of a study of metals loadings to Sitcum Waterway (Norton and Johnson 1985b), WDOE found that:

- The Port has had a practice of collecting recoverable ore and washing the remaining ore into Sitcum Waterway
- EP toxicity tests on samples of ore spilled at Terminal 7 indicated that lead and zinc ores would be designated as dangerous wastes under WDOE's 1984 Dangerous Waste Regulations when spilled or discharged into the environment
- High concentrations of zinc, lead, and copper were present in sediments along the north side of the channel, in front of Terminal 7.

To prevent the release of spilled ores at the Terminal 7 unloading facility, improved materials handling procedures are required. Control technologies that may be applicable to control metals contamination from the Port's Terminal 7 include

- Discontinuation of washing unrecovered ore into Sitcum Waterway
- Construction of a surface water collection/diversion system to prevent metal-laden runoff from entering Sitcum Waterway
- Treatment of surface water by physical or chemical means (e.g., filtration, carbon adsorption, flocculation/coagulation)
- Construction of sedimentation ponds to remove particulate matter prior to discharge of stormwater to Sitcum Waterway

- Use of particle curtains or other barriers to prevent atmospheric transport of ore dust during unloading and handling activities
- Use of aprons between ships and dock during unloading operations.

3.6.3.2 Storm Drains SI-172, SI-176, and SI-717--

Storm drains SI-172, SI-176, and SI-717 are confirmed sources of metals (arsenic, copper, lead, and zinc) to Sitcum Waterway. Although loading estimates have been calculated for each of these storm drains (and four others in Sitcum Waterway), caution must be exercised when using these loadings to prioritize sources since most loadings were calculated based on a single sampling event. Storm drains SI-172, SI-176, and SI-717 were given a higher priority for further source evaluation and control because these three drains were clearly the largest known sources of metals, and the total combined loadings represented over 94 percent of the total known metals loading for Sitcum Waterway.

Storm drain SI-172, commonly referred to as the North Corner Drain, is a confirmed source of metals (arsenic, copper, lead, and zinc) to Sitcum Waterway. The 60-in concrete pipe conveys stormwater runoff from the commercial/industrial area east of the waterway to the northeast corner of the waterway. The drainage area of approximately 214 ac is bounded by East 11th Street, Port of Tacoma Road, Lincoln Avenue, and Milwaukee Way (Figure 16). The North Corner drain (SI-172) is the largest known source of arsenic and copper to Sitcum Waterway. Estimated loadings are 1.8 lb/day of arsenic and 0.57 lb/day of copper, representing approximately 92.6 percent and 41 percent of the total respective loadings to this waterway. SI-172 is ranked second in source loadings of zinc (1.23 lb/day) and third for lead (0.36 lb/day). The North Corner drain is the largest confirmed source of combined metals loading to Sitcum Waterway (estimated to be 3.96 lb/day of metals) and has a high priority for source control.

Several sources may be contributing to the high metals concentration of surface water discharged from SI-172: motor vehicles, unauthorized storm sewer connections, ore spillage from railroad cars, and infiltration of groundwater contaminated by Tacoma Landfill leachate and buried ASARCO slag.

Storm drain SI-176 is a 30-in concrete outfall that discharges stormwater runoff from the 170-ac Sealand facility located on the south side of the waterway. The entire site is paved and has several sets of railroad tracks that access the West Sitcum Terminal. Most of the southwest shore, on which the Sealand facilities are located, has been rip-rapped with ASARCO slag (Kucinski, 6 August 1985, personal communication). Discharge SI-176 is the largest source of lead and zinc to Sitcum Waterway. Estimated loadings are 1.56 lb/day of lead and 1.75 lb/day of zinc. These loadings represent nearly 53 percent (lead) and 38 percent (zinc) of the total loadings of these metals. Discharge SI-176 is the second largest source of arsenic and copper. Estimated loadings are 0.068 lb/day of arsenic and 0.38 lb/day of copper. Storm drain SI-176 is the second largest confirmed loading to Sitcum Waterway (estimated to be 3.76 lb/day of metals), and has high priority for source control. High metals loadings in the surface water collected in the drainage area of storm drain SI-176 may be the result of direct discharge or spills of materials containing metals, or infiltration of groundwater contaminated by ASARCO slag.

Storm drain SI-717 is located approximately 1,200 ft from the head of Sitcum Waterway on the northwest bank. SI-717 collects surface water runoff from the Port of Tacoma's Terminal 7. Drain SI-717 is the second largest known source of lead and zinc to Sitcum Waterway. Estimated loadings are 0.90 lb/day of lead and 1.23 lb/day of zinc, representing over 30 percent of the total known loadings of these metals to Sitcum Waterway. Storm drain SI-717 is ranked third in source loadings of arsenic (0.056 lb/day) and of copper (0.36 lb/day). Based on available source information, drain SI-717 is ranked third for total metals loading to Sitcum Waterway. Spillage of ores and ore concentrates at the Port of Tacoma's Terminal 7 is most likely the largest source of metals within the drainage area of SI-717.

Remedial technologies that may be applicable to reduce metals loadings to Sitcum Waterway via storm drains SI-172, SI-176, and SI-717 include

- Stormwater controls, Section 2.3.5
- Improvement in ore handling procedures by the Port of Tacoma to minimize spillage from railcars
- Improvement in ore off-loading procedures by the Port of Tacoma to minimize spillage at the facility and within the drainage area (particularly SI-717)
- Inspection of Sealand facilities for potential sources of metals and implementation of control measures, if applicable.
- Stabilization of slag to prevent further leaching of metals into the waterway (e.g., cement).

3.6.3.4 Unknown Sources--

Contaminants in Sitcum Waterway for which additional source identification is necessary are N-nitrosodiphenylamine, dibenzofuran, 1-methyl(2-methylethyl)-benzene, diterpenoid hydrocarbons, LPAH and HPAH. These organic compounds are all priority 3 contaminants. For accurate identification of sources, the discharges to Sitcum Waterway should be sampled for these specific compounds.

3.6.4 Sediment Remedial Action

Sediments within Sitcum Waterway have been assigned an environmental significance ranking of 4 based on observed contamination levels, toxicity, and biological effects. Therefore, it is recommended that this area be evaluated further for sediment remedial actions to reduce the environmental threat associated with the priority contaminants in the sediments. Remediation of the existing contaminated sediments should be implemented only after the present sources of contamination have been effectively controlled.

Options for management of contaminated sediments in Sitcum Waterway include capping, in situ treatment/stabilization, and dredging. Capping may not be a feasible option for management of contaminated sediments within Sitcum Waterway because maintenance dredging will be required to provide clearance for deep draft vessels using the Sealand facilities and the Port of Tacoma's Terminal 7. Sediment management technologies are discussed in Chapter 2 of this report.

In general, the priority contaminants are classified as primarily particle-bound, indicating that hydraulic dredging may be the preferred sediment removal method. The volume of contaminated sediment within Sitcum Waterway is estimated to be 80,667 yd^3. This volume was estimated using a surface area of 50 ac, computed with a planimeter, and an average sediment depth of 1.0 ft, estimated from recent subbottom profiles (Raven Systems and Research 1984). For the purpose of this preliminary volume calculation, contamination was assumed to extend through the soft sediment layer. However, it may extend into the harder underlying sediment layers. Additional deep core sampling is necessary to determine the actual vertical extent of contamination.

3.6.5 Data Needs

Some data gaps for Sitcum Waterway are associated with non-definitive boundaries of the area of concern, while others are associated with the inconclusive identification of potential sources. Data needs specific to Sitcum Waterway include

- Additional source identification for compounds identified in Section 3.6.3.4:

    Priority 3 - N-nitrosodiphenylamine, dibenzofuran, 1-methyl(2-methylethyl)benzene, diterpenoid hydrocarbons, LPAH, HPAH

- Investigation of the mechanisms by which metals are reaching the stormwater collection system within the Sitcum Waterway drainage area (e.g., unauthorized storm connections, contaminated groundwater, spills)

- More precise definition of the spatial and vertical extent of the problem area (i.e., surface sediment sampling beyond the mouth of Sitcum Waterway and deep sediment coring).

3.7 HYLEBOS WATERWAY SEGMENT 1

3.7.1 Physical Description

Segment 1 of Hylebos Waterway is located at the southeast end of the waterway, and extends from the head of the waterway (16,500 ft from the mouth) to approximately 13,500 ft from the mouth (Figure 12). Facilities located along this segment include Tacoma Boatbuilding to the north; Wasser Winters and Louisiana Pacific at the head of the waterway; and Glacier Sand and Gravel, and Weyerhaeuser to the south. Glacier Sand and Gravel (NPDES No. WA003042) and Tacoma Boatbuilding (State Permit No. WA003710-9) are the only permitted discharges to this segment of the waterway. Non-permitted discharges to this segment for which loading data exists include an 8-in concrete pipe (HY-040), Hylebos Creek (HC-000), Kaiser Ditch (HK-052), and runoff from the log sort yards. Additional non-permitted discharges include 10 surface water outfalls (Figure 13). Surface water runoff from Kaiser Aluminum, Cascade Timber Yard #2, Dunlap Towing, and Weyerhaeuser are also discharged to Hylebos Waterway Segment 1 via Kaiser Ditch. The upper turning basin is located within this segment at the head of Hylebos Waterway and measures approximately 1,000 ft at its widest point. Water depth in this segment is fairly constant at 40 ft below MLLW (Raven Systems and Research 1984). Sediments are typically 66 percent fine-grained, with approximately 20 percent clay. (Tetra Tech 1985). Accumulation of soft sediments ranges from 1 to 4 ft in Segment 1 (Raven Systems and Research 1984). Past dredging activities include maintenance dredging by the U.S. Army Corps of Engineers in 1964, 1966, and 1972; by Tacoma Boatbuilding in 1976; by Glacier Sand and Gravel in 1973 and 1982; and by Weyerhaeuser in 1970, 1972 and 1976. Glacier Sand and Gravel has applied for a 5- to 10-yr maintenance dredging permit with the U.S. Army Corps of Engineers. The industry has completed sediment sampling and will apply for a shoreline permit from the City of Tacoma (Thornton, J., 23 April 1985, personal communication). The WDOE is considering requiring the industry to sample sediments every 3 yr during the maintenance dredging project.

3.7.2 Extent of Contamination

Results of the Commencement Bay Nearshore/Tideflats Remedial Investigation indicate that HPAH, arsenic, and zinc are priority 1 contaminants. Priority 2 contaminants are phenol and antimony. Priority 3 contaminants are phthalate esters, ethylbenzene, tetrachloroethene, xylenes, 1-methyl(2-methylethyl)benzene, methylpyrenes, and total volatile solids (TVS). The area of concern is defined as the entire segment, based on chemical and biological analyses of sediment samples collected during this project at Stations HY-11, HY-12, HY-13, HY-14, HY-15, HY-16, H7-17, HY-18, and HY-19 (Figure 18); and on evaluation of historical sediment data. Analyses indicated elevated contaminant concentrations and several abnormal biological conditions at all stations within this segment. Sediment bioassays indicated significant oyster larvae and amphipod toxicity. Benthic analyses indicated low polychaete and mollusc counts within this segment. Fish in Hylebos Waterway had significant accumulations of mercury, PCBs, and phthalates in muscle tissues, and significantly elevated prevalences of liver lesions.

The problem area was highly contaminated with HPAH and most of the metals. Distributions of these chemicals in Segment 1 were not clearly separated from those in Segment 2. Both groups of substances exhibited high EAR near the south side of the channel at Stations HY-15 and HY-16. Compositional differences and similarities were generally too weak to either confirm or refute that PAH originated from the same source. Arsenic and copper were present at relatively high levels compared to those of the other metals, but only arsenic was present above toxicity or benthic effects AET at some stations. Although this composition was not observed at most stations in Commencement Bay, it was characteristic of some sediments along the Ruston-Pt. Defiance Shoreline.

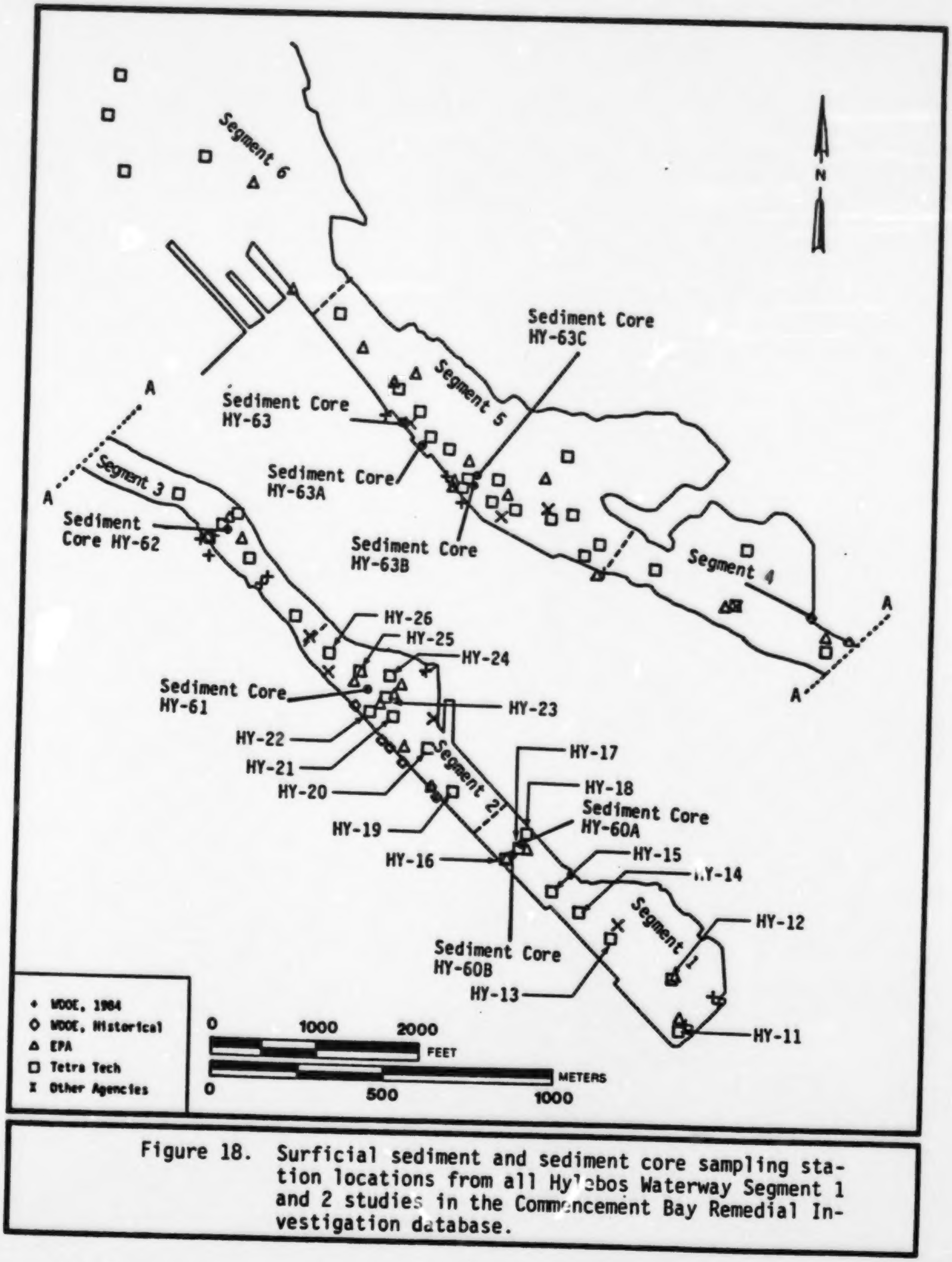

N
Segment 6
Segment 5
Segment 4
Segment 3
Segment 2
Segment 1
A
A
A
A
Sediment Core HY-63C
Sediment Core HY-63
Sediment Core HY-63A
Sediment Core HY-63B
Sediment Core HY-62
HY-26
HY-25
HY-24
Sediment Core HY-61
HY-23
HY-22
HY-21
HY-20
HY-19
HY-17
HY-18
Sediment Core HY-60A
HY-16
HY-15
HY-14
HY-12
Sediment Core HY-60B
HY-13
HY-11
+ WDOE, 1984
◇ WDOE, Historical
△ EPA
□ Tetra Tech
X Other Agencies
0
1000
2000
FEET
METERS
0
500
1000

Figure 18. Surficial sediment and sediment core sampling station locations from all Hylebos Waterway Segment 1 and 2 studies in the Commencement Bay Remedial Investigation database.

3.7.3 Contaminant Sources

In general, sources of metals to Hylebos Waterway Segment 1 have been well identified. Sources and their respective contaminant loadings are presented in Table 7. The log sorting yards have been identified as the first priority source of total metals. Combined loadings from these facilities range from 1.8 lb/day of lead to 9.5 lb/day of arsenic. Log sorting yards within the drainage of Segment 1 include Wasser Winters, Louisiana Pacific, Weyerhaeuser, Dunlap Towing, and Cascade Timber Yard #2. The Weyerhaeuser log sorting yard is not a significant source of metals, most likely because its yard is paved. Hylebos Creek is the second priority source of metals to Segment 1. Major metals loadings to Hylebos Creek include Fife ditch and two landfills (U.S. Gypsum and B&L Landfill). The third priority source of metals is Kaiser Ditch, which carries surface water runoff from Kaiser Aluminum and Chemical Corporation, Weyerhaeuser, Dunlap Towing, and Cascade Timber Yard #2 to the waterway. Only Kaiser Ditch has consistently been documented as a source of PAH to Hylebos Waterway Segment 1. This is attributed primarily to historical practices of sludge disposal at Kaiser Aluminum and Chemical Corporation, and possibly to atmospheric deposition of PAH that are released from plant vents that eventually enter Hylebos Waterway via stormwater runoff. Source identification for PAH is complicated by several potential sources (i.e., Kaiser Aluminum and Chemical Corporation, General Metals, and Tacoma Boatbuilding), the lack of strong spatial trends, and limited data. Additionally, these contaminants are expected to be ubiquitous in an industrialized area like Commencement Bay from activities such as burning of fossil fuels and release of petroleum products into the environment. Although the WDOE maintains records of spill incidents, this is a recent activity (since about 1970) and would not be useful to quantify PAH loading from historical spills. Also, the PAH loading from unreported spills and bilge pumping cannot be quantified. Possible sources of tetrachloroethene to Hylebos Segment 1 may be Pennwalt Chemical Corporation and Tacoma Boatbuilding.

3.7.3.1 Log Sorting Yards--

Log sorting yards are the first priority for implementation of source control remedies because these facilities are collectively the largest source of metals to Hylebos Waterway Segment 1 and because enforcement action to reduce contaminant discharge from these facilities is currently being planned. Loadings from log sorting yards represent approximately 76 percent of the arsenic, 34 percent of the zinc, 51 percent of the copper, and 53 percent of the lead to this segment. The log sorting yards within the Segment 1 drainage area are Wasser Winters, Louisiana Pacific, Dunlap Towing, Cascade Timber Yard #2, and Weyerhaeuser. A WDOE study of the log sorting yards as sources of metals to Commencement Bay (Norton and Johnson 1985a) found that slag particles containing metals were being pulverized by heavy equipment, and that metals were mobilized by a combination of acidic rainwater, stormwater runoff, and wood alcohol. WDOE concluded that these yards are sources of metals to Hylebos Waterway via surface water runoff and possibly via groundwater contamination.

Daily metals loadings from log sorting yards adjacent to Hylebos Waterway were calculated on the basis of data provided by Norton and Johnson (1985a) to be 9.5 lb/day of arsenic, 4.3 lb/day of zinc, 3.0 lb/day of copper,

TABLE 7. CONTAMINANT LOADINGS AND RELATIVE PERCENTAGES FOR HYLEBOS WATERWAY, SEGMENT 1

Contaminant	Discharge						
	HC-000	HY-040	HY-052	Wasser Winters[a]	Cascade Timber Yard #2[a]	Louisiana Pacific[a]	Weyerhaeuser
PAH							
LPAH							
loading, lb/day	ND	ND	<0.046				
% of loading to segment			100				
% of loading to waterway			<100				
HPAH[b]							
loading, lb/day	ND	ND	<0.15				
% of loading to segment			100				
% of loading to waterway			<100				
Metals							
Arsenic[b]							
loading, lb/day	2.4		0.65	4.4	0.74	4.3	0.018
% of loading to segment	19.19		5.20	35.18	5.91	34.38	0.14
% of loading to waterway	7.04		1.91	12.90	2.17	12.61	0.05
Copper							
loading, lb/day	2.4		0.43	1.0	1.2	0.73	0.056
% of loading to segment	41.27		7.39	17.19	20.63	12.55	0.97
% of loading to waterway	26.94		4.83	11.22	13.47	8.19	0.63

TABLE 7. (Continued)

Lead							
loading, lb/day	1.1		0.51	0.62	0.72	0.49	0.016
% of loading to segment	31.83		14.76	17.94	20.83	14.18	0.46
% of loading to waterway	22.45		10.41	12.65	14.69	10.00	0.33
Zinc[b]							
loading, lb/day	6.5		1.8	1.5	1.6	1.0	0.2
% of loading to segment	51.59		14.29	11.90	12.70	7.94	1.58
% of loading to waterway	24.41		6.76	5.63	6.01	3.76	0.75
Chlorinated Hydrocarbons							
Ethenes[b]		ND					
loading, lb/day	0.27		0.052				
% of loading to segment	83.85		16.15				
% of loading to waterway	3.39		0.65				

[a] Log sorting yard that used ASARCO slag as ballast.

[b] Priority contaminant.

and 1.8 lb/day of lead for four of the five yards within Segment 1 (i.e., all but Dunlap Towing). The WDOE has held two meetings with owners and operators of the log sorting yards to encourage joint action to control runoff from these sites. At this time, no action has been taken by these facilities. WDOE plans to take enforcement action against all unpaved log sorting facilities that used ASARCO slag as ballast (Pierce, R., 22 April 1985, personal communication). Surface water control technologies that have been discussed by WDOE and log sorting yard operators include paving the yards and constructing sedimentation ponds. Removal of the ASARCO slag material, construction of shallow slurry walls, or construction of collection drains may be considered if it is determined that these log sorting facilities are contaminating shallow groundwater. Remedial action for shallow groundwater may only be necessary if it is determined that this contaminant pathway contributes significant metals loadings to the waterway.

3.7.3.2 Hylebos Creek--

Hylebos Creek is a major source of metals to Hylebos Waterway. It is ranked as the largest source of zinc, and the second largest source of arsenic, copper, and lead (the log sorting yards are the largest source). Metals loadings include 6.5 lb/day of zinc, 2.4 lb/day of arsenic, 2.4 lb/day of copper, and 1.1 lb/day of lead. Loadings from Hylebos Creek represent approximately 51.6 percent of the zinc, 19.2 percent of the arsenic, 41.3 percent of the copper, and 31.8 percent of the lead to this segment. Although source identification did not typically extend past the immediate vicinity of Commencement Bay, two landfills (U.S. Gypsum and B&L Landfills) and two drainage ditches (Fife and Marine View Drive) are considered to contribute these metals to Hylebos Creek. The U.S. Gypsum site was used to landfill baghouse dust from the manufacture of insulation made with ASARCO slag. This site was excavated and contaminated materials were removed in December, 1984 (Pierce, R., 22 April 1985, personal communication). Monitoring of the site has been implemented to determine effectiveness of the cleanup. It is believed discharge of metals from this site will decrease with time and will not contribute to future loadings of metals to the Hylebos Creek. The B&L Landfill, which is not a permitted site, has received soil and wood wastes contaminated with ASARCO slag from log sorting yards. The WDOE is currently preparing to have corrective action taken to have contaminated materials removed from this site (Pierce, R., 23 July 1985, personal communication). A WDOE study of metals contamination within the Hylebos Creek drainage area (Johnson and Norton 1985a) concluded that these two landfills have been major sources of metals to Hylebos Waterway via Hylebos Creek. Until corrective measures are implemented, B&L Landfill will continue to be a source of metals. Sources of metals within the drainage areas of Fife Ditch and Marine View Drive have not been identified, but observed metals concentrations are within typical ranges for urban runoff.

Source control of metals for Hylebos Creek is focused on controlling individual discharges from the major metals sources within the drainage area, including B&L Landfill, Fife Ditch, and Marine View Drive Ditch. Recent and planned remedial action at the two landfill sites achieved through enforcement by regulatory agencies will alleviate two major sources of metals to Hylebos Creek. The U.S. Gypsum site should continue to be monitored. It is recommended that regulatory agencies proceed with plans to have corrective action taken for the mitigation of contaminated materials from the B&L Landfill. It is also recommended that the state proceed with plans to require surface water control measures at all log sorting facilities and that groundwater contamination at these facilities be investigated.

3.7.3.3 Kaiser Ditch--

Sampling at Kaiser Ditch has confirmed the release of HPAH and metals in this discharge. On the basis of available source information, Kaiser Ditch is the largest source of HPAH to Hylebos Waterway (0.15 lb/day). Kaiser Ditch is also a source of metals. Estimated loadings including 0.65 lb/day of arsenic, 0.51 lb/day of lead, 0.43 lb/day of copper, and 1.8 lb/day of zinc. Based on available source data, these loadings from Kaiser Ditch represent approximately 5.2 percent of the arsenic, 14.8 percent of the lead, 7.4 percent of the copper, and 14.3 percent of the zinc to Hylebos Waterway Segment 1.

It appears that discharge of HPAH from the Kaiser Ditch is largely due to the deposition of these contaminants between 1969 and 1971 during dredging of the Kaiser Aluminum and Chemical Corporation wet scrubber settling ponds. This is substantiated by sediment core data from Hylebos Waterway off Kaiser Ditch showing high concentrations of HPAH in sediments buried beneath relatively less contaminated recent deposition. It is likely that the observed ongoing discharge of PAH from the Kaiser Ditch is primarily a result of the transport of historically deposited contaminants adhered to ditch sediments that are being deposited into Hylebos Waterway. Ongoing release of PAH through stack emissions and plant vents may be occurring at Kaiser Aluminum and Chemical Corporation. Discharge of metals is also believed to be ongoing. A study conducted by CH2M HILL (1983) indicated that copper and zinc were both present in stormwater runoff from the Kaiser Aluminum and Chemical Corporation property. Loadings of these metals were calculated at 0.20 lb/day of copper and <0.20 lb/day of zinc. Other sources of metals to the Kaiser Ditch include surface runoff from Cascade Timber Yard #2, Dunlap Towing, and Weyerhaeuser log sorting yards.

No remedial measures for the sediments in Kaiser Ditch are recommended at this time until ongoing sources of metals and PAH from Kaiser Aluminum and Chemical Corporation and other sources have been controlled, and the transport of contaminants from this ditch are investigated. Deep sediment cores from Kaiser Ditch should be taken to determine the veritcal extent of contamination prior to evaluation of remedial actions for Kaiser Ditch sediments. Surface water runoff controls should be implemented at the Kaiser facility to control migration of contaminants via this route. Possible options include sedimentation ponds and collection and treatment (see Chapter 2 for surface water control technologies). Surface water controls at the log sorting yards will decrease the metals loadings to the Kaiser Ditch and to Hylebos Waterway. Additional source control of PAH released from stack emissions and exhaust vents at Kaiser Aluminum and Chemical Corporation may be necessary to reduce loadings to Hylebos Waterway.

Remedial action may be necessary for the contaminated sediments in Kaiser Ditch, if, after implementation of the above source control measures at Kaiser Aluminum and Chemical Corporation and the log sorting yards, residual loadings of PAH and metals are not effectively controlled from the Kaiser Ditch. Alternatives that may be applicable to reduce the transport of contaminants from the Kaiser Ditch include

- Removal of Kaiser ditch sediments
- Diversion of surface water to prevent contact with contaminated sediments in Kaiser Ditch
- Installation of culvert or other type conduit to convey storm water to prevent contact with contaminated sediments in Kaiser Ditch
- In situ stabilization of contaminated sediments (e.g., paving, clay liner).

3.7.3.4 Unknown Sources--

For several of the priority contaminants in Hylebos Waterway Segment 1, confirmation of sources is not possible with existing data. Contaminants for which additional source identification is needed include phenol, phthalate esters, ethylbenzene, xylenes, 1-methyl(2-methylethyl)benzene, and methylpyrenes. Discharge monitoring for these specific contaminants is necessary to identify the sources. Although some source information is available for tetrachloroethene and HPAH, it appears that confirmed loadings are relatively small, and it is unlikely that all potential sources have been identified and monitored. Therefore, additional source identification is necessary for tetrachloroethene and HPAH.

3.7.4 Sediment Remedial Actions

Sediments within Hylebos Waterway Segment 1 have been assigned an environmental significance ranking of 4 based on observed contamination, toxicity, and biological effects. Therefore, it is recommended that this area be considered for remedial action to remove the environmental and public health threat associated with the priority contaminants in the sediments. Remediation of the existing contamination is recommended only after the present sources of contaminants have been effectively controlled.

Options for management of contaminated sediments within Hylebos Waterway Segment 1 include capping, in situ treatment/stabilization, and dredging. Capping, although not eliminated from consideration, probably does not have much applicability in Hylebos Waterway due to frequent maintenance dredging required to provide clearance for deep draft vessels that use this waterway. The volume of contaminated sediment within Hylebos Waterway Segment 1 is estimated to be 295,240 yd^3. This volume was estimated using a surface area of 61 ac, computed using a planimeter, and an average sediment depth of 3 ft, estimated from cross sections of the upper turning basin (Raven Systems and Research 1984). For the purpose of this preliminary volume calculation, contamination is assumed to extend through the soft sediment layer. However, it may extend into the harder underlying sediment layers. Additional deep core sampling is necessary to determine the actual vertical extent of contamination.

3.7.5 Data Needs

Several data needs were identified that hinder the development and evaluation of potential remedial alternatives for the problem area in Hylebos Waterway Segment 1. Some data gaps are associated with non-definitive boundaries of the problem area, while others are associated with the inconclusive identification of potential sources. Specific data needs include

- Additional source identification of priority contaminants listed in Section 3.7.4:

  Priority 1 - HPAH
  Priority 2 - Phenol
  Priority 3 - Phthalate esters, ethylbenzene, tetrachloroethene, xylenes, 1-methyl(2-methylethyl)benzene, methylpyrenes

- Additional source identification within the Hylebos Waterway Segment 1 drainage area if significant metals loadings continue after control of known sources
- Investigation of General Metals as possible source of metals, organic solvents, and PAH to Segment 1
- Investigation of Tacoma Boatbuilding as a possible source of metals and organic solvents in Hylebos Segment 1
- Determination of whether contaminant contribution from Kaiser Ditch is from historical deposits or from ongoing discharges from Kaiser Aluminum and Chemical Corporation
- Relative contaminant loading from Kaiser Aluminum and Chemical Corporation, Dunlap Towing, Cascade Timber Yard #2 and Weyerhaeuser to the Kaiser Ditch and control of these confirmed sources
- Additional sediment sampling to determine if PCBs observed in historical sediments of Segment 2 are present in Segment 1 at these same depths, coordinated with a waterway source and sediment investigation for PCBs
- Contribution from atmospheric loading of HPAH from Kaiser Aluminum and Chemical Corporation in stormwater runoff
- Additional deep core sampling in Kaiser Ditch to determine the vertical extent of PAH contamination.

3.8 HYLEBOS WATERWAY SEGMENT 2

3.8.1 Physical Description

Segment 2 of Hylebos Waterway is located in the southeastern portion of the waterway, extending approximately from 10,900 ft to 13,500 ft from the mouth of the waterway. The lower turning basin is located within Segment 2 and measures approximately 750 ft at its widest point. Recent subbottom profiling of Hylebos Waterway showed that mid-channel depths in this segment average approximately 33 ft below MLLW. Depth varied across the channel bottom between 30 ft and 35 ft below MLLW. Channel cross sections indicated that sediment accumulation is between 1 and 5 ft in the lower turning basin (Raven Systems and Research 1984). Sediments within the Hylebos Waterway are typically silty sands with an average composition of 64 percent fine-grained material and an average clay content of 20 percent. Past dredging activities include maintenance dredging by the U.S. Army Corps of Engineers in 1951, 1958, 1962, and 1964 through 1966; by General Metals in 1972, 1974, 1975, 1979, and 1984; and by Pennwalt Chemical Corporation in 1982. As of April 22, 1985, there were no planned or pending dredging activities in this segment.

Facilities located along the banks of Hylebos Waterway Segment 2 include Jones Chemical and General Metals to the north, and Dunlap Towing, Cascade Timber Yard #2, and Pennwalt Chemical Corporation to the south (Figure 12). General Metals (state permit No. 5006) and Pennwalt Chemical Corporation (HY-058, NPDES WA0003115), are the only permitted discharges to Segment 2. Non-permitted discharges to Segment 2 for which loading data exist include Morningside Ditch (HM-028) on the north bank, and East Channel Ditch (HY-054), Pennwalt East Seep (HY-700), Pennwalt West Seep (HY-701), Pennwalt East Stormwater drain (HY-708), a 6-in concrete pipe (HY-056), Pennwalt discharge pipe (HY-709), and groundwater seeps (HY-061) along the south bank. There are eight additional surface water discharges to Hylebos Waterway Segment 2 (Figure 13).

3.8.2 Extent of Contamination

Results of the Commencement Bay Nearshore/Tideflats Remedial Investigation indicated that PCBs are priority 1 contaminants in Segment 2. Priority 2 contaminants include HPAH, nickel, arsenic, and tetrachloroethene. Mercury, copper, zinc, and lead were also identified as priority 2 contaminants based on an evaluation of historical data of intertidal sediments. Priority 3 contaminants are hexachlorobutadiene, chlorinated benzenes, phthalate esters, phenol, benzyl alcohol, dibenzothiophene, methylphenanthrenes, and methylpyrenes. The area of concern is defined as the eastern portion of the segment, based on biological and chemical analysis of sediment samples collected at Stations HY-20, HY-21, HY-22, and HY-23 (Figure 18) and evaluation of historical sediment data. Analysis indicated elevated contaminant concentrations at stations within this segment and several abnormal biological conditions. Sediment bioassays indicated significant oyster larvae and amphipod toxicities. Fish in Hylebos Waterway had significant accumulations of mercury, phthalates, and PCBs in muscle tissues and significantly elevated prevalences of liver lesions.

Concentrations of PCBs in surficial sediments of Segment 2 ranged from <200 to 2,000 ug/kg. PCB concentrations peaked about 12,000 ft from the mouth of the waterway, off Pennwalt Chemical Corporation. The peak observed at this location is believed to be the result of dredging in the area by Pennwalt in 1982 and therefore may not be representative of recent sedimentation. This hypothesis is supported by sediment analyses performed just prior to dredging indicating that surficial sediments had concentrations of <100 ug/kg PCBs (Riley 1981). Furthermore, concentrations present in surficial sediments after dredging were similar to those found in deeper layers of undisturbed portions of the waterway. In general, deep cores indicated that historical discharges were greater than current discharges. Concentrations of PCB at Station 3 (Riley 1981) were typically 10 times greater in the lower horizon (0.30-0.35 m) than in surficial sediments. There are no known ongoing discharges of PCBs to Hylebos Waterway Segment 2. Kaiser Ditch is the only documented source of PCBs in the entire waterway.

The problem area within Hylebos Waterway Segment 2 was highly contaminated with HPAH and most of the metals, although the concentrations of only some metals exceed toxicity or benthic AET. Distributions of these chemicals in Segment 2 were not clearly separate from those in Segment 1. Both groups of contaminants (especially HPAH) exhibited high EAR on the south side of the waterway at Station HY-22. Compositional differences and similarities were generally too weak to either confirm or refute that PAH originate from the same source. Evaluation of the historical sampling data showed metals were present at relatively high concentrations in the intertidal sediments along the south side of the waterway. PCBs and chlorobenzene concentrations were also elevated above AET in this problem area.

3.8.3 Contaminant Sources

Contaminant loadings are presented in Table 8. All but two of the identified discharges are associated with Pennwalt Chemical Corporation. Available data indicate that Pennwalt is the largest source of chlorinated ethenes, chlorinated benzenes, chlorinated butadienes, arsenic, zinc, and mercury to Hylebos Waterway Segment 2. Contaminants are entering Hylebos Waterway from Pennwalt Chemical Corporation via plant effluent, surface water runoff, and groundwater. Enforcement actions have been initiated by WDOE regarding violations of NPDES permit limitations and contamination of soils on the property from the recent sodium chlorate and potassium dichromate spill. Morningside Ditch is a confirmed but minor source of chlorinated ethenes, arsenic, zinc, and mercury. Loadings for Morningside Ditch are typically less than 1 percent of the total loadings to Segment 2, except for zinc, which is 9 percent. The East Channel Ditch is also a source of arsenic and zinc, but these loadings are most likely from surface water runoff from the Dunlap Towing and the Cascade Timber log sorting yard, which used ASARCO slag as ballast. As discussed in Section 3.7, WDOE plans to take enforcement action against all unpaved log sorting facilities that used ASARCO slag as ballast.

3.8.3.1 Pennwalt Chemical Corporation--

Pennwalt Chemical Corporation is an ongoing source of PAH, chlorinated hydrocarbons (butadienes and ethenes), arsenic, zinc, and mercury to Hylebos Waterway Segment 2. Current discharges associated with Pennwalt include the main plant outfall (HY-058), a surface drain (HY-055), groundwater seeps (HY-700 and HY-701), and the groundwater beneath the property (shallow and intermediate aquifers). Discharges HY-056, HY-708, and HY-709 conveyed surface water runoff from the Pennwalt facility to Hylebos Waterway until 1981, when they were discontinued and their flows were routed through the main plant outfall. For the purposes of quantifying average loadings and determining relative source contributions, loadings from these discharges will be added to the main plant discharge. This probably results in a slight overestimate of the actual plant discharge. However, due to the relatively small amounts of most contaminants (except arsenic) and the

TABLE 8. CONTAMINANT LOADINGS AND RELATIVE PERCENTAGES FOR HYLEBOS WATERWAY, SEGMENT 2

Contaminant	Discharge											
	HM-028	HY-054[c]	HY-055[b]	HY-056[b]	HY-058[b]	HY-061	HY-700[b]	HY-701[b]	HY-708[b]	HY-709[b]	Groundwater Beneath Pennwalt	Pennwalt Total
PCB[a]	ND	ND		ND	ND		ND			ND		
loading, lb/day												
% of loading to segment												
% of loading to waterway												
PAH	D	D		D		D	D	D				
LPAH loading, lb/day												
% of loading to segment												
% of loading to waterway												
HPAH[a] loading, lb/day												
% of loading to segment												
% of loading to waterway												
Chlorinated Hydrocarbons												
Ethenes[a] loading, lb/day	0.0055	0.00055		0.034	0.92		0.0061	0.0024			0.119	1.0815
% of loading to segment	0.50	0.05		3.13	84.60		0.56	0.22			10.94	99.45
% of loading to waterway	0.07	<0.01		0.43	11.56		0.08	0.03			1.49	13.59

TABLE 8. (Continued)

Benzenes[a] loading, lb/day	<0.21	ND		ND	ND	ND	0.000059	ND		ND	0.000059
% of loading to segment	99.97						0.03				0.03
% of loading to waterway	32.35						<0.01				<0.01
Butadienes[a] loading, lb/day	ND	ND		ND	ND	ND	0.00004	0.00005		ND	0.00009
% of loading to segment							44.44	55.56			100
% of loading to segment							0.15	0.19			0.34
Metals											
Arsenic[a] loading, lb/day	0.0045	0.68	0.51	7.2	4.3		0.00075	0.12	0.57	1.3	14.00075
% of loading to segment	0.03	4.8	3.60	50.80	30.34		<0.01	0.85	0.40	9.17	95.16
% of loading to waterway	0.01	1.99	1.50	21.11	12.61		<0.01	0.35	0.17	3.81	39.55
Zinc[a] loading, lb/day	0.97	0.56	0.003	0.0057	9.3		0.0007	0.0024	0.022	0.0019	9.3347
% of loading to segment	8.94	5.15	0.02	0.05	85.60		<0.01	0.02	0.20	0.02	85.91
% of loading to waterway	3.64	2.10	<0.01	0.02	34.93		<0.01	<0.01	0.08	<0.01	35.03
Mercury[a] loading, lb/day	0.0013	0.00017	0.00011	0.0017	0.28		0.000045	0.000096	0.00023	0.00032	0.282501
% of loading to segment	0.46	0.06	0.04	0.60	98.60		0.02	0.03	0.08	0.11	99.48
% of loading to waterway	0.42	0.05	0.04	0.55	90.22		0.01	0.03	0.07	0.10	91.02

[a] Priority contaminant.

[b] Discharge associated with Pennwalt Chemical Corp.

[c] Includes loading from HY-055.

ND = Not detected.

D = Detected.

range in contaminant concentrations from these discharges, the possible error is believed to be insignificant.

PAH have been detected in discharges HY-055, HY-056, HY-700, and HY-701, but loadings based on average flows and concentrations are minor. Chlorinated hydrocarbons have been detected in discharges HY-055, HY-056, HY-058, HY-700, and HY-701, and in groundwater aquifers beneath the plant site. Pennwalt is the largest source of chlorinated ethenes to Hylebos Waterway Segment 2. An estimated combined loading of approximately 1.08 lb/day of chlorinated ethenes, representing 95 percent of the total known loading to Segment 2, is discharged from Pennwalt via the main plant outfall (average loading of 0.95 lb/day), surface drains, and groundwater (average loading of 0.119 lb/day). Chlorinated butadienes have been detected in the groundwater seeps (HY-700 and HY-701) along the bank in front of the Pennwalt property, and the estimated loading averages 0.00009 lb/day. These loadings are the only confirmed sources of chlorinated butadienes to Segment 2. They represent 100 percent of the total known loading to this segment, but less than 1 percent of the total loading to the entire waterway.

Arsenic has been detected in discharges from the main plant outfall (HY-058), surface drains (HY-055, HY-056, HY-708, and HY-709), and groundwater seeps (HY-700 and HY-701) associated with Pennwalt. The combined arsenic loading is estimated to be 14 lb/day, which represents 95 percent of the known loading to Segment 2 and nearly 40 percent of the total known loading to Hylebos Waterway. This loading is probably a slight underestimation, since the groundwater beneath Pennwalt is contaminated with arsenic (Eaton, T., 22 April 1985, personal communication) and it is uncertain whether this loading was fully quantified by existing data from seeps and infiltration into the storm drains. Mercury has been detected in discharges from the main plant outfall (HY-058), surface drains (HY-055, HY-056, HY-708, and HY-709), and groundwater seeps (HY-700 and HY-701). Pennwalt is the largest source of mercury to Hylebos Waterway, with an estimated loading of 0.283 lb/day, representing nearly 100 percent of the total known discharge to Segment 2 and approximately 91 percent of the total known loading to Hylebos Waterway.

Currently, there are several regulatory activities involving the Pennwalt facility. The NPDES permit for Pennwalt Chemical Corporation expired in 1980. The WDOE is drafting a new permit and is expected to issue it by August 15, 1985 (Eaton, T., 29 July 1985, conference). Pennwalt has been in chronic noncompliance with their NPDES permit conditions for pH, chlorine residual, and suspended solids. From January, 1984 to February, 1985, Pennwalt had six violations of both pH and residual chlorine limitations and four violations of suspended solids limitations (quarterly monitoring) (Eaton, T., 10 May 1985, personal communication). Because of concern about groundwater contamination due to the leaching of arsenic from pennite (sodium arsenite) sludges buried on Pennwalt Chemical Corporation property, WDOE required Pennwalt to perform a study, including soil and groundwater monitoring, to determine the environmental effects of the buried pennite sludges. The study revealed arsenic concentrations of 50 to 70 mg/L in the groundwater beneath the burial site. Resolution of this issue is still pending. The WDOE is also concerned about the potential for groundwater contamination from the unlined lagoons used for dewatering of brine muds and asbestos wastes from the chlorine cells at the Pennwalt facility. Over the last several years, however, waste volumes discharged to this lagoon have decreased. This decrease has mitigated overflows during periods of high precipitation and has reduced the groundwater seeps emanating from the banks in front of the Pennwalt facility (Eaton, T., 10 May 1985, personal communication).

On January 3, 1985, approximately 75,000 gal of a sodium chlorate and potassium dichromate solution was spilled at the Pennwalt Chemical Corporation facility when a tank collapsed. Most of the spill ran into Hylebos Waterway and only a small amount infiltrated into the ground. WDOE has taken enforcement action against Pennwalt to insure the proper cleanup of the spill area. Pennwalt was ordered to collect samples and to define the spatial extent and degree of contamination. An area of approximately 1 ac in size and 6 in deep was determined to be contaminated with > 5 mg/kg of total chromium. WDOE plans to issue an administrative order requiring the removal of contaminated soils. Pennwalt will most likely construct a temporary treatment lagoon to recover the chromium, (Eaton, T., 22 April 1985, personal communication). WDOE also ordered Pennwalt to collect samples of the waterway sediments and have them analyzed for hexavalent chromium. Pennwalt has until mid-August to submit the analyses results to WDOE (Eaton, T., 30 July 1985, personal communication).

Based on elevated PCB concentrations in the sediments off the Pennwalt Chemical Corporation outfall, the WDOE initiated PCB sampling of the area adjacent to the electrical equipment, including the storm drains. Samples were collected in February, 1985, and while results of the analyses have been received by the WDOE, they were not available at the time of this writing (August 6, 1985).

WDOE believes a significant quantity of organic chemicals may be leaving the Pennwalt Chemical Corporation facility absorbed onto solids in the effluent waste stream but undetected due to high dilution. To quantify this amount, the WDOE is considering requesting Pennwalt Chemical Corporation and other chemical manufacturing companies to perform analyses for organic contaminants on the filter solids from their effluents (Eaton, T., 10 May 1985, personal communication).

Contaminants are entering Hylebos Waterway and surrounding environment via the direct discharge of process wastewaters, surface water runoff, and groundwater from Pennwalt Chemical Corp. Control of this source will require implementation of a remedial plan that integrates several technologies. Discussion of in-plant control technologies is not within the scope of this report. However, contaminant loadings from process effluents are significant and must be addressed in a source control plan. Discharge of process effluent and the rerouted surface water via the main plant outfall is the largest source of zinc and the second largest source of arsenic, copper, and chlorinated ethenes to Hylebos Waterway.

Contamination of surface water runoff may be resulting from any or all of the following situations: contaminated surface soils, chemical spills and leaks, and historical deposition of contaminated sediments within surface water collection system. Potentially applicable remedial technologies to control contaminated surface waters at Pennwalt Chemical Corporation include

- Excavation of contaminated soils and fill with clean material
- Removal of contaminated sediments from the waste lagoon, including underlying contaminated soils; installation of a liner; and enlargement of the berm around the lagoon to prevent overflow
- Capping, covering, or pavement of contaminated areas to reduce migration of contaminants
- Inspection and cleaning of surface water collection system and channels to prevent mobilization of historically deposited contaminants and infiltration of contaminated groundwater
- Inspection of all above-ground lines and tanks for leaks, and repair if necessary
- Surface water controls, Section 2.3.

A combination of the above technologies may be necessary to control contaminants entering Hylebos Waterway via surface water runoff.

Groundwater beneath Pennwalt Chemical Corporation is the fourth largest known discharge of chlorinated ethenes to Hylebos Waterway. Groundwater is also a confirmed source of arsenic, with a concentration of 50 to 70 mg/L (Eaton, T., 10 May 1985, personal communication). Contamination of groundwater may result from leaching of contaminants from the waste lagoon, contaminated soils, and sodium pennite sludge buried on-site; exfiltration from buried waste and process lines; leaking from storage tanks; and chemical spills. Potentially applicable remedial technologies to control groundwater contamination at Pennwalt Chemical Corporation include

- Excavation of contaminated soils and fill with clean materials
- Removal of contaminated sediments from waste lagoon, including underlying contaminated soils; installation of a liner; and enlargment of the berm around the lagoon to prevent overflow
- Capping, covering, or pavement of contaminated areas to reduce migration of contaminants
- Inspection of underground lines and tanks (if applicable) for cracks, breaks, and leaking connections. Repair, if necessary
- Groundwater controls, Section 2.4.

The above technologies vary considerably in the extent to which they mitigate groundwater contamination. For example, capping will prevent the further contamination of overlying soils and reduce or prevent the driving force of surface water infiltration. However, existing contamination will remain and the soils may continue to be a source of contaminants to the groundwater. For full control, a combination of groundwater pumping and treatment in conjunction with contaminated soil remediation may be necessary. Groundwater control technologies are discussed in further detail in Chapter 2, Remedial Technologies.

3.8.3.2. Morningside Ditch--

Morningside Ditch (HM-028) is an ongoing source of PAH, chlorinated hydrocarbons (benzenes and ethenes), arsenic, copper, lead, and zinc. The Morningside Ditch collects surface water from the north side of Hylebos Waterway along Marine View Drive, from approximately 11,000 ft to 15,300 ft from the mouth of the Hylebos. Drainage channels are composed of open ditches and pipes, and provide surface drainage for commercial activities, including Woodworth Sand and Gravel, Jones Chemical, and Manke Lumber Yard. The Coski Landfill is within the drainage area of the Morningside Ditch and it is conceivable that leachate from this landfill reaches the Hylebos Waterway via this drainage. Also, a waste sludge disposal site used by Occidental Chemical Corporation is located north of Marine View Drive, between HM-031 and HM-032. Currently the Tacoma-Pierce County Health Department is collecting additional information and updating the existing report of surface drainage within the Commencement Bay area. This information is due for release late in 1985 as part of the final report of the Marine Resource Program (Pierce, D., 10 May 1985, personal communication).

Morningside Ditch is the second largest known source of chlorinated benzenes (<0.21 lb/day) to Hylebos Waterway. Metals loadings from the Morningside Ditch are relatively minor. Rankings of this source for copper, lead, and zinc are tenth, ninth, and eighth, respectively. Concentrations of priority chemicals in the intertidal sediments off the Morningside Ditch were not significantly elevated. For these reasons, it was concluded that Morningside Ditch is probably not a major source of contaminants to Hylebos Waterway Segment 2. In the absence of definitive sources of contamination and of sediment data implicating Morningside Ditch as a problem source, no technologies are recommended for Morningside Ditch.

3.8.3.3. Unknown Sources--

For most of the priority contaminants in Hylebos Waterway Segment 2, confirmation of sources is not possible with existing data. Contaminants for which source identification is needed include PCBs, HPAH, nickel, copper, zinc, lead, phthalate esters, phenol, benzyl alcohol, dibenzothiophene, methylphenanthrenes, and methylpyrenes. Additional discharge monitoring for these specific contaminants is necessary to identify sources. Some information is available on sources of HPAH, arsenic, tetrachloroethene, mercury, hexachlorobutadiene, and chlorinated benzenes.

3.8.4 Sediment Remedial Action

Sediments within Hylebos Waterway Segment 2 have been assigned an environmental significance ranking of 4 based on observed contamination, toxicity, and biological effects. Therefore, it is recommended that this area be considered for remedial action to remove the environmental and public health threat associated with the priority contaminants in the sediments. Remediation of the existing contamination is recommended only after the present sources of contaminants have been effectively controlled.

Options for management of contaminated sediments within Hylebos Segment 2 include capping, in situ treatment/stabilization, and dredging. Capping probably has little application within Hylebos Waterway because frequent maintenance dredging will be required to provide clearance for the deep draft vessels using this waterway. Remedial action including source control and/or sediment removal within Hylebos Waterway Segment 2 should be coordinated with activities proposed for Segment 1, since the two problem areas within these segments merge spatially, and contaminant spillover occurs between the two problem areas. The volume of contaminated sediment within Hylebos Waterway Segment 2 is estimated at 106,480 yd^3. This volume was estimated using a surface area of 22 ac, computed with a planimeter, and an average sediment depth of 3 ft, estimated from recent subbottom profiles (Raven Systems and Research 1984). For the purpose of this preliminary volume calculation, contamination was assumed to extend through the soft sediment layer. Additional deep core sampling is necessary to determine the actual vertical extent of contamination.

3.8.5 Data Needs

Several data needs were identified that hinder the development and evaluation of potential remedial alternatives for the problem area in Hylebos Waterway Segment 2. Some data gaps are associated with non-definitive boundaries of the problem area, while others are associated with the inconclusive identification of potential sources. Specific data needs include

- Additional source identification of priority contaminants listed in Section 3.8.3.3:

  Priority 1 - PCBs
  Priority 2 - HPAH, nickel, arsenic, mercury, copper, zinc, lead
  Priority 3 - Hexachlorobutadiene, chlorinated benzenes, phthalate esters, phenol, benzyl alcohol, dibenzothiophene, methylphenanthrenes, methylpyrenes

- More precise definition of the vertical extent of contamination by deep core sediment sampling

- Vertical distributions of PCBs, and the extent to which sediment contamination is due to current discharges (if any). Information that may be useful for this determination includes sedimentation rates, dating of sediment cores, and additional source investigation

- A survey to identify all potential past and current sources of PCBs, including identification of electrical equipment containing PCB oil

- Additional investigation at Pennwalt Chemical Corporation to determine the in-plant source of arsenic.

3.9 CITY WATERWAY, SEGMENT 2

3.9.1 Physical Description

Segment 2 of City Waterway is commonly referred to as the Wheeler-Osgood Waterway, which was formed from the old western channel of the Puyallup River. Wheeler-Osgood Waterway is ringed by abandoned buildings, warehouses, and several small industries with undetermined operations. Hygrade Foods, formerly (prior to 1960) Carsten's Meat Packing Company, is located on the north bank of Wheeler-Osgood Waterway (Figure 19). Currently, there are no permitted discharges to Wheeler-Osgood Waterway and 11 non-permitted discharges (Figure 10). Storm drain CW-254 is a 30-in outfall that discharges surface water runoff at the head of the waterway from a drainage area of less than 1 ac. CW-254 is the only drain for which loading data are available. Wheeler-Osgood Waterway is approximately 1,500 ft in length, with an average width of 225 ft. This is an inactive waterway with limited access during low tides. Since much of Wheeler-Osgood Waterway was exposed during the recent subbottom profiling, sediment accumulation was not determined for the upper portion. Sediment depth was not determined with any accuracy because the coring device was unable to penetrate through the accumulated wood wastes in this portion of the waterway. Sediments within City Waterway are typically 64 percent fine-grained material with an average clay content of 18 percent. These sediments are anoxic, with organic carbon content of 10.9 to 18 percent. Visual examination of the sediments indicated considerable accumulation of wood debris in Wheeler-Osgood Waterway.

3.9.2 Extent of Contamination

Results of the Commencement Bay Nearshore/Tideflats Remedial Investigation indicated that HPAH, cadmium, copper, zinc, dichlorobenzenes, LPAH, lead, n-nitrosodiphenylamine, 4-methylphenol, phenol, biphenyl, total volatile solids, total organic carbon, and oil and grease are priority 2 contaminants in Wheeler-Osgood Waterway. There were no priority 1 or 3 contaminants identified for this waterway. The area of concern is defined as the entire waterway, based on biological and chemical analyses of sediment samples collected at Station CI-16 (Figure 20) and evaluation of historical sediment data. Analyses indicated elevated contaminant concentrations and several abnormal biological conditions. Sediment bioassays indicated significant oyster larvae toxicity, and benthic studies revealed low numbers of total benthic organisms, polychaetes, molluscs, and crustaceans. Fish from City Waterway had significant accumulation of PCBs in muscle tissue.

EAR for metals and HPAH in the Wheeler-Osgood problem area were comparable to those at adjacent stations in the main channel. Selected chlorobenzenes and 4-methylphenol were found at high concentrations in this problem area and all exhibited clear gradients of decreasing concentrations in the main channel of City Waterway with distance from the mouth of the Wheeler-Osgood branch. These latter compounds distinguished Wheeler-Osgood Waterway from the rest of City Waterway, but the full extent of the possible contamination is uncertain because of the limited numbers of samples collected.

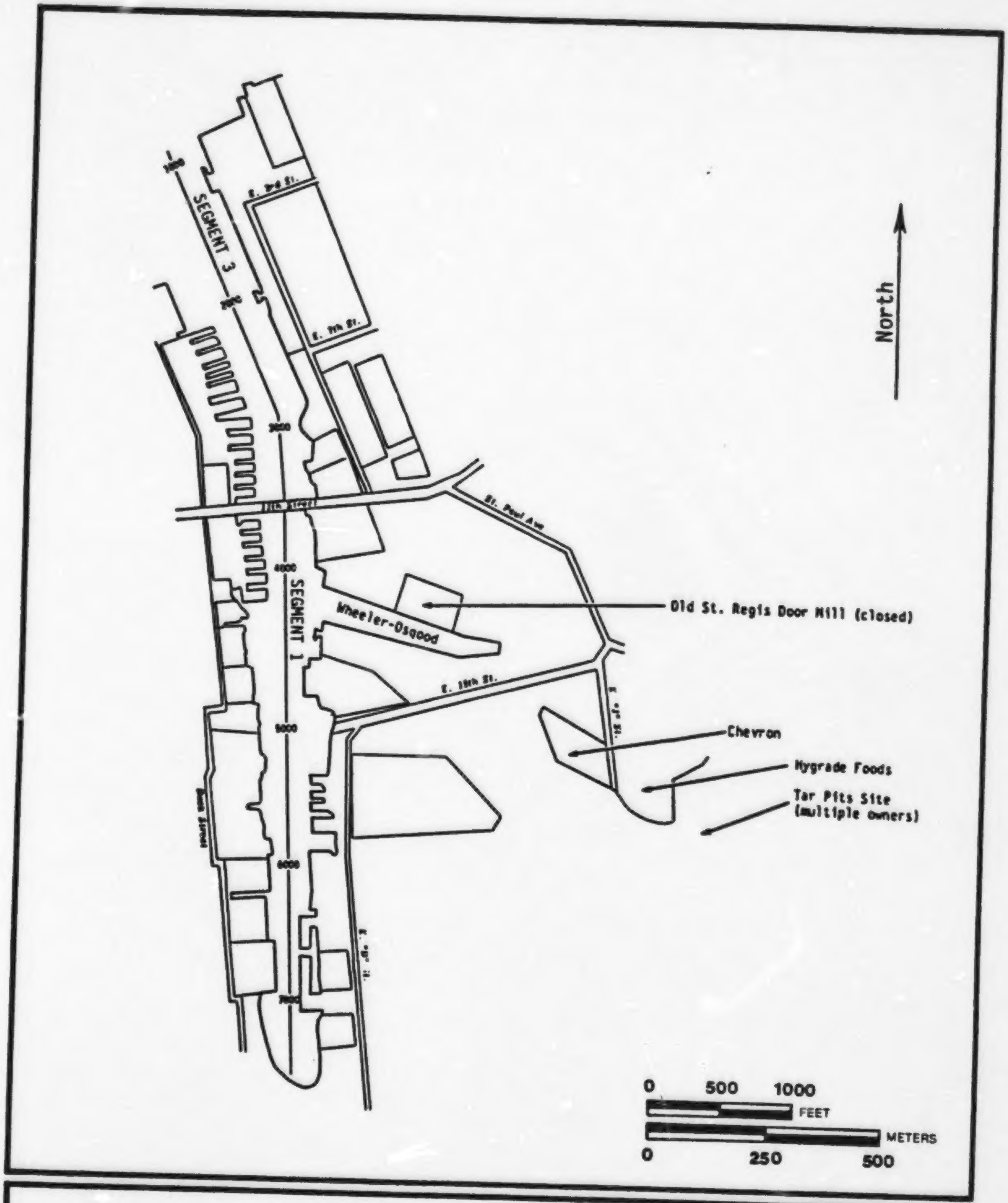

1000
SEGMENT 3
E. 3rd St.
2000
E. 9th St.
3000
11th Street
St. Paul Ave
4000
SEGMENT 1
Wheeler-Osgood
Old St. Regis Door Mill (closed)
E. 15th St.
5000
Chevron
Hygrade Foods
Tar Pits Site
(multiple owners)
Dock Street
6000
7000
North
0 500 1000
FEET
METERS
0 250 500

Figure 19. Industries surrounding City Waterway Segment 2 (Wheeler-Osgood Waterway).

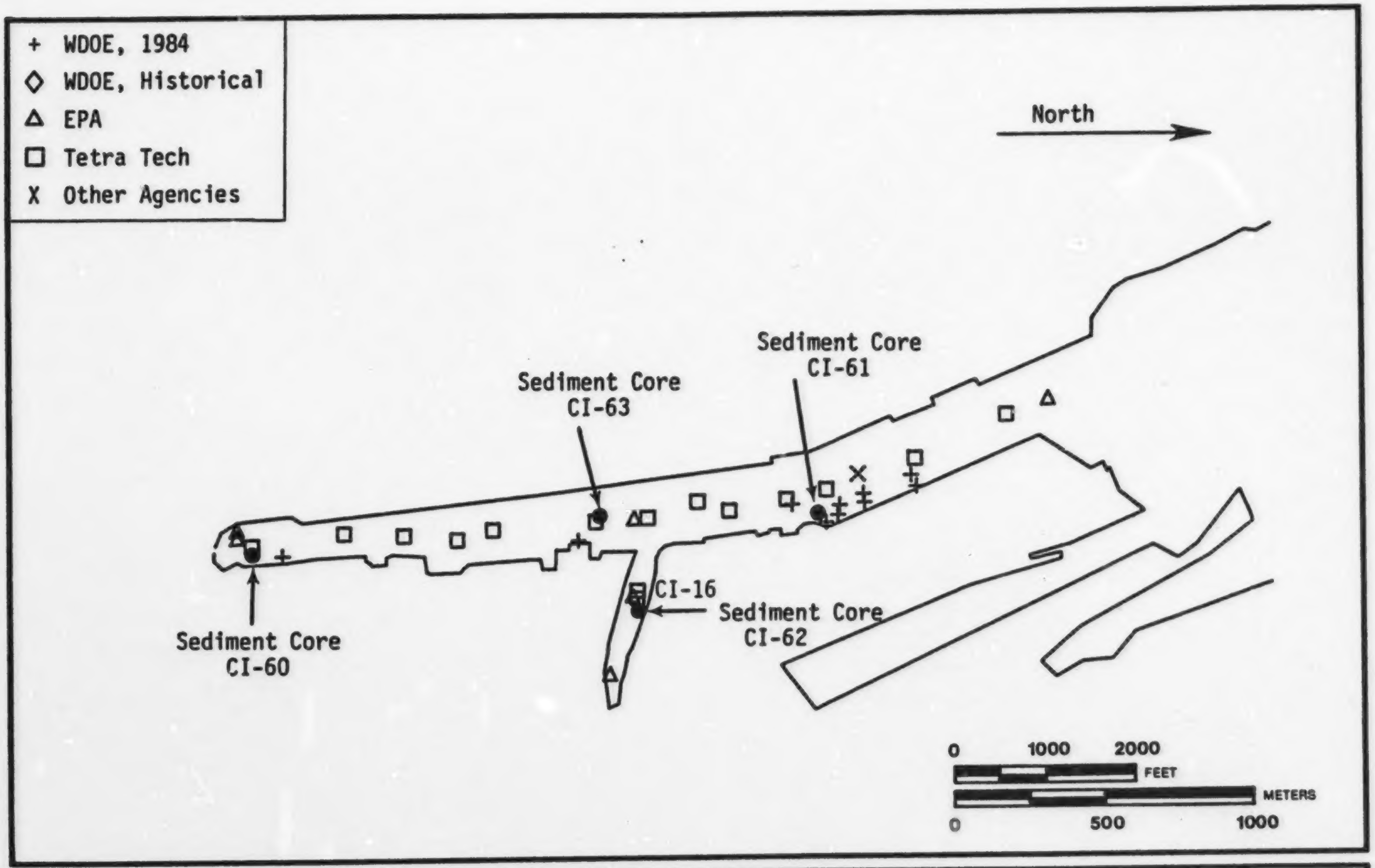

+ WDOE, 1984
◇ WDOE, Historical
△ EPA
□ Tetra Tech
X Other Agencies
North
Sediment Core CI-61
Sediment Core CI-63
CI-16
Sediment Core CI-62
Sediment Core CI-60
0 1000 2000 FEET
0 500 1000 METERS

Figure 20. Surficial sediment and sediment core sampling station locations from all studies in City Waterway.

3.9.3 Contaminant Sources

Evaluation of contaminant sources in Wheeler-Osgood Waterway indicates that storm drain CW-254 is the only confirmed ongoing source of cadmium, zinc, lead, organic matter, and solids to this waterway. Contaminant loadings from CW-254 are presented in Table 4. WDOE conducted a survey of priority pollutants and other contaminants in City Waterway Storm drains as part of the Commencement Bay Nearshore/Tideflats Remedial Investigation (Johnson and Norton 1984). CW-254 is considered to be a major source of organic matter and solids. Estimated organic loading is believed to be high due to the high specific conductance of the sample resulting from tidal infuence. No ongoing sources could be identified for HPAH, dichlorobenzenes, n-nitrosodiphenylamine, 4-methylphenol, phenol, and biphenyl. Carsten's Packing Company may have been a historical source of dichlorobenzenes, given the association of these compounds with degreasing and tanning of animal hides; however, there is no evidence this compound was used by them. Three possible sources of 4-methylphenol were identified. The first is St. Regis Door Mill, which is a possible historical source due to the association of 4-methylphenol with the wood products industry. The second is the migration of contaminated groundwater and surface water from the old coal gasification plant (Tar Pits Site). A third potential source is degradation of wood chip debris buried in the sediments.

It was not possible to determine definitely whether contaminant loading in Wheeler-Osgood Waterway is due to ongoing sources or to historical discharges. Several data gaps prevented this determination, including the following: inconclusive source identification, limited discharge monitoring, few surface sediment samples, unknown transport mechanisms into and away from this waterway, and unquantified sedimentation rate. Over the last several years, much of the commercial and industrial activity within this waterway has declined and presently active industries are reportedly connected to the sanitary sewer system. Contaminant concentrations in surficial sediments (0-2 cm) are several times lower than in sediment samples composited over the top 14 cm of a core collected in the same area. These data indicate that any recent or ongoing sources within Wheeler-Osgood are substantially less than in the past. A slow sedimentation rate is indicated by these data, resulting in slow burial of contaminated sediments, so that only a thin layer at the surface reflects a reduced contaminant discharge. Alternatively, a more rapid sedimentaton rate might be indicated because there is a constant source of solids and organic matter from the storm drains emptying into Wheeler-Osgood Waterway. This waterway is fairly isolated and is not subject to vigorous flushing during tidal exchanges. The sedimentation rate should be determined. Available sampling data indicate that CW-254 is an ongoing source of metals, solids, and organic matter. Loading data were not available for the other 12 discharges.

3.9.3.1 Storm Drain CW-254--

Storm drain CW-254 is a 30-in steel outfall that discharges surface water runoff at the head of Wheeler-Osgood Waterway. Drain CW-254 is the only confirmed ongoing source of LPAH, mercury, zinc, lead, cadmium, and organic matter to this waterway. The drainage area is relatively small (<1 ac) and is located to the east of Wheeler-Osgood Waterway. Active industries within this drainage area are Chevron and Hygrade Foods. Historically, a very large source of organic matter to Wheeler-Osgood Waterway was Carsten's Meat Packing Company, whose slaughtering wastes were discharged via CW-254. Cross connections with the sanitary sewer were also a source of organic loading to Wheeler-Osgood prior to sewer separation in 1969. It is believed that most of the organic loading has been diverted to the sanitary sewer, but recent sampling of CW-254 indicated that this outfall still contributes COD. Sampling in 1981 and 1982 showed COD concentrations of 170 to 490 mg/L (Johnson and Norton 1984). Using these data, loading of organic matter, as measured by COD, was estimated to be 673 lb/day based on an average flow of 0.28 MGD. This loading is believed to be an overestimate because discharge samples, collected during high tide conditions, had high concentration of chlorides and other ions that increased the apparent COD concentration determined by the test method (Yake, W., 29 May 1985, personal communication). Concentrations of metals from CW-254 were typically below those concentrations observed in stormwater runoff from residential areas (Galvin et al. 1982). Metals loadings to Wheeler-Osgood Waterway from this drain were calculated on the basis of data from Johnson and Norton (1984) to be 0.0004 lb/day of cadmium, 0.19 lb/day of zinc, and 0.097 lb/day of lead. Organic and solids loadings from CW-254 continue to be a major source, although historical loadings were most likely greater before sanitary and storm sewers were separated, and before slaughtering house wastes were diverted to the sanitary sewer. LPAH may be entering the storm sewers through spillage of petroleum products at the Chevron facility. Loading of LPAH from CW-254 has been calculated at 0.036 lb/day (Tetra Tech 1985).

In summary, contaminants may be entering Wheeler-Osgood via CW-254 by one or more of the following: cross connections with the sanitary sewer system, resuspension of material in the storm sewers from historical discharge, unauthorized commercial/industrial connections to the storm sewer system, and product spillage. Potentially applicable remedial technologies to reduce concentrations of contaminants reaching Wheeler-Osgood Waterway via discharge CW-254 include

- Inspection and cleaning, if necessary, of accumulated solids from the storm sewers and catch basins within the drainage area of Wheeler-Osgood Waterway
- Storm water controls, Section 2.3.5.

3.9.3.2 Unknown Sources--

No confirmed sources have been identified for several of the priority contaminants in Wheeler-Osgood Waterway. Contaminants for which source identification was not possible are HPAH, dichlorobenzenes, N-nitrosodiphenylamine, phenol, and biphenyl. Some information is available for possible sources of cadmium, copper, zinc, LPAH, and 4-methylphenol, but source confirmation for these contaminants was not possible.

3.9.4 Sediment Remedial Actions

Sediments within Wheeler-Osgood Waterway have been assigned an environmental significance ranking of 4 based on observed contamination levels, toxicity, and biological effects. It is therefore recommended that this problem area be considered for remedial action to remove the environmental threat associated with the priority contaminants in the sediments. Remediation of the existing contamination is recommended only after the present sources of contaminants have been effectively controlled.

Options for management of contaminated sediments within Wheeler-Osgood Waterway include capping, in situ treatment/stabilization, and dredging. Wheeler-Osgood is one of the few problem areas within the Commencement Bay Nearshore/Tideflats study area where capping has high potential as a remedial technology if groundwater sources can be effectively controlled. This is due to minimal commercial activity around this waterway requiring waterway access. Dredging of Wheeler-Osgood Waterway, if evaluated as a sediment management option, may be most effectively accomplished with hydraulic methods since the contaminants of concern are primarily sediment-bound. Since much of this waterway is intertidal, special consideration should be given to portable and land-based dredging units. The configuration and physical characteristics of this waterway also make it particularly suitable for the use of cofferdams with mechanical dredges. Contaminated sediments are estimated to cover 7 ac. However, the volume of contaminated sediments could not be estimated because sediment depth was not accurately determined. If groundwater is determined to be a source of contaminants to Wheeler-Osgood Waterway, it is likely that lower sediment layers are also contaminated. Additional deep core sampling is necessary to determine the actual vertical extent of contamination.

3.9.5 Data Needs

Several data needs were identified that hinder the development and evaluation of potential remedial alternatives for the problem area in Wheeler-Osgood Waterway. Some data gaps are associated with the physical processes within the waterway, including sediment deposition rate and transport from this waterway. Other data gaps are associated with the inconclusive identification of potential sources. Specific data needs for Wheeler-Osgood Waterway include

- Additional source identification for those compounds identified in Section 3.9.3.2:

  Priority 2 - HPAH, cadmium, copper, zinc, dichlorobenzenes, LPAH, lead, N-nitrosodiphenylamine, 4-methylphenol, phenol, and biphenyl

- Determine sedimentation rates within Wheeler-Osgood Waterway to define temporal contaminant deposition. Delineation of historical versus ongoing or recent contaminant deposition is complicated because sediment deposition rates within this waterway and their changes over time are unknown

- Dating of deep sediment cores to determine deposition dates of contamination

- Sediment transport between Wheeler-Osgood and City Waterways. Generally, it is believed that Wheeler-Osgood Waterway is isolated from the rest of City Waterway. However, spatial trends of some contaminants (e.g., dichlorobenzenes) suggest that this waterway may be a source to the main waterway

- Potential contribution of LPAH from Chevron and West Coast Grocery via groundwater and surface water drains
- Potential contribution of PAH and 4-methyphenol via groundwater migration from the Tar Pits site
- Monitoring storm results from drains in Wheeler-Osgood Waterway for priority contaminants, loadings, and evaluation of source control tehnologies.

3.10 MIDDLE WATERWAY

3.10.1 Physical Description

Middle Waterway is situated between St. Paul Waterway to the north and City Waterway to the south. Industries along the north shore include Paxport Mills, located about three-fourths of the length from the head of the waterway, and Champion International, which occupies most of the remaining area to the southeast. Coast Craft, a custom woodworking company, is located along the southwest shore of the waterway. Washington Belt and Drive, Western Machine, Pacific Yacht Basin, a fire station, and a power substation are located at the head of the waterway. Several maritime industries are located along the west shore, including Foss Launch and Tug (a Dillingham Maritime Company), Marine Industries Northwest, and Cook's Marine Specialties (Figure 21). There are no permitted discharges to Middle Waterway and six non-permitted discharges. A surface water drain (MD-200) and a groundwater seep (MD-199) are located at the head of the waterway. Two iron pipe outfalls (MD-202 and MD-220) and a catch basin with inlet pipes (MD-203) are located at the mouth of the waterway on the west shore. Surface drain MD-201, located at the head of the waterway, was recently abandoned (Pierce, R., 15 July 1985, personal communication).

In general, Middle Waterway has remained relatively unchanged since before 1923. Much of this waterway remains intertidal, with the upper half exposed during low tides. There has been only one Corps of Engineers dredging project since 1970. Past dredging projects by private companies include Puget Sound Plywood in 1972 and 1978, and Paxport Mills in 1982. Middle Waterway is approximately 3,500 ft in length, with an average width of 350 ft. Water depth increases from the head of the waterway toward the mouth, and recent transects indicate the east side of the channel is deeper than the west (Raven Systems and Research 1984). Water depths along the east side typically increased from 0 ft below MLLW at the head to 25 ft below MLLW at the mouth of the waterway. Along the west side, water depths increase from 0 ft below MLLW to approximately 23 ft below MLLW, then decrease to 13 ft below MLLW immediately in front of the mouth. Both transects show a sharp increase in water depth, below 40 ft MLLW, at the mouth of the waterway. Cross-sections of Middle Waterway show a significant accumulation (1-4 ft) of soft sediment in the middle and eastern side of the channel. Sediments within Middle Waterway are typically 54 percent fine-grained material with a clay content of approximately 12 percent.

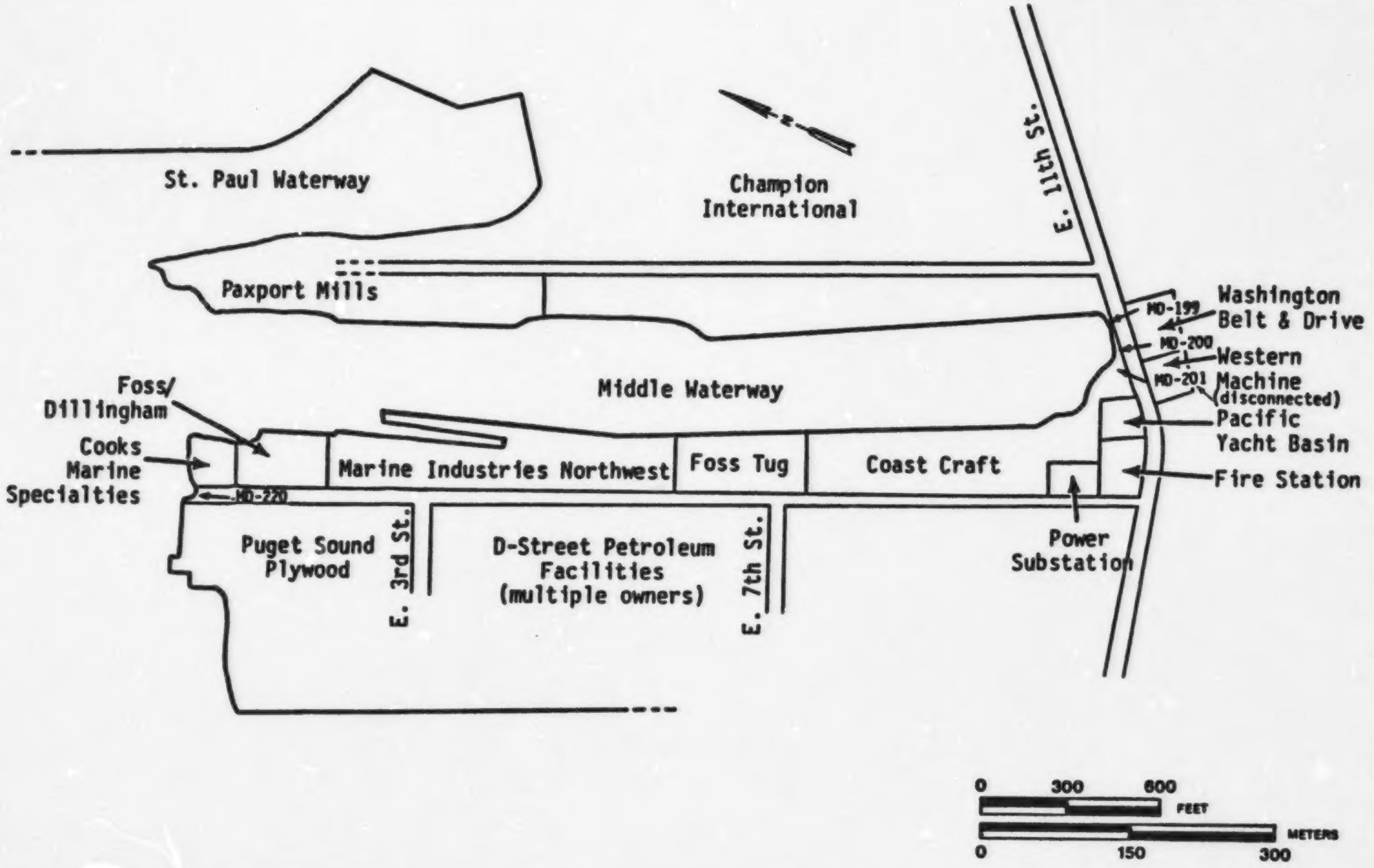

St. Paul Waterway
Champion International
E. 11th St.
Paxport Mills
Washington Belt & Drive
MD-199
MD-200
Western Machine (disconnected)
MD-201
Middle Waterway
Foss/ Dillingham
Cooks Marine Specialties
MD-220
Marine Industries Northwest
Foss Tug
Coast Craft
Pacific Yacht Basin
Fire Station
Power Substation
Puget Sound Plywood
E. 3rd St.
D-Street Petroleum Facilities (multiple owners)
E. 7th St.
N
0
300
600
FEET
0
150
300
METERS

Figure 21. Major industries along and discharges to Middle Waterway (boundries approximate, based on drive-by inspection).

3.10.2 Extent of Contamination

Results of the Commencement Bay Nearshore/Tideflats Remedial Investigation indicate that mercury and copper are priority 2 contaminants in Middle Waterway. HPAH, arsenic, zinc, dichlorobenzenes, LPAH, pentachlorophenol, lead, 4-methylphenol, phenol, dibenzothiophene, diterpenoid hydrocarbons, and methylpyrenes are priority 3 contaminants. No priority 1 contaminants were identified in this waterway. The area of concern is defined as the entire waterway, based on chemical and biological analyses of sediment samples collected at stations MD-11, MD-12, and MD-13 (Figure 22). Analyses indicated elevated contaminant concentrations at all stations and several abnormal biological conditions. Fish in Middle Waterway had significantly elevated prevalences of liver lesions and significant accumulation of PCB in muscle tissues.

Pentachlorophenol was detected at the head of the waterway (Station MD-11) at 620 ug/kg dry weight. This concentration, and two others in Blair Waterway, were the only Commencement Bay stations where pentachlorophenol concentrations exceeded 150 ug/kg dry weight. There were no biological data available from any of these three stations, which limited the analysis of AET for pentachlorophenol. Concentrations of copper, arsenic, and mercury increased regularly from the head to maximum values near the mouth (Station MD-13), while lead (and to a lesser extend zinc) concentrations peaked in the middle of the waterway at Station MD-12. The EAR of copper and mercury were among the highest observed in this study away from Segment 2 of the Ruston-Pt. Defiance Shoreline. These two metals exceeded their toxicity and benthic effects AET at station MD-13.

LPAH concentrations decreased from the head to the mouth of the waterway. LPAH and HPAH concentrations exceeded their AET only at Station MD-11 where the highest concentration in all available data was found. Naphthalene, 2-methylnaphthalene, and phenanthrene were the PAH that exhibited the highest EAR. HPAH also decreased in concentration from the head to the mouth of the waterway, but the composition differed along the waterway. HPAH in sediments near the head and the mouth of the waterway were dominated by pyrene and benzo(a)pyrene and had low levels of methylpyrenes. Sediments from Station MD-12 in the center of the waterway had higher relative concentrations of methylpyrenes and benzo(a)pyrene than did sediments from the other stations.

3.10.3 Contaminant Sources

In general, confirmed sources for most of the priority contaminants within Middle Waterway cannot be identified, although several likely sources have been suggested for further investigation. Champion International, Paxport, and Coast Craft are potential sources of pentachlorophenol and other phenolic compounds, since these contaminants are associated with wood products industries. Copper and mercury are also components of wood preserving materials that may have been used by these wood products industries. Another potential source of metals contamination is the use of sandblasting grits and the other ship repair activities by the maritime industries including Foss Launch and Tug, Marine Industries Northwest, and Cooks Marine Specialties located along the west shore of Middle Waterway. Leaching of metals from ASARCO slag used as riprap along the west shore is another possible source.

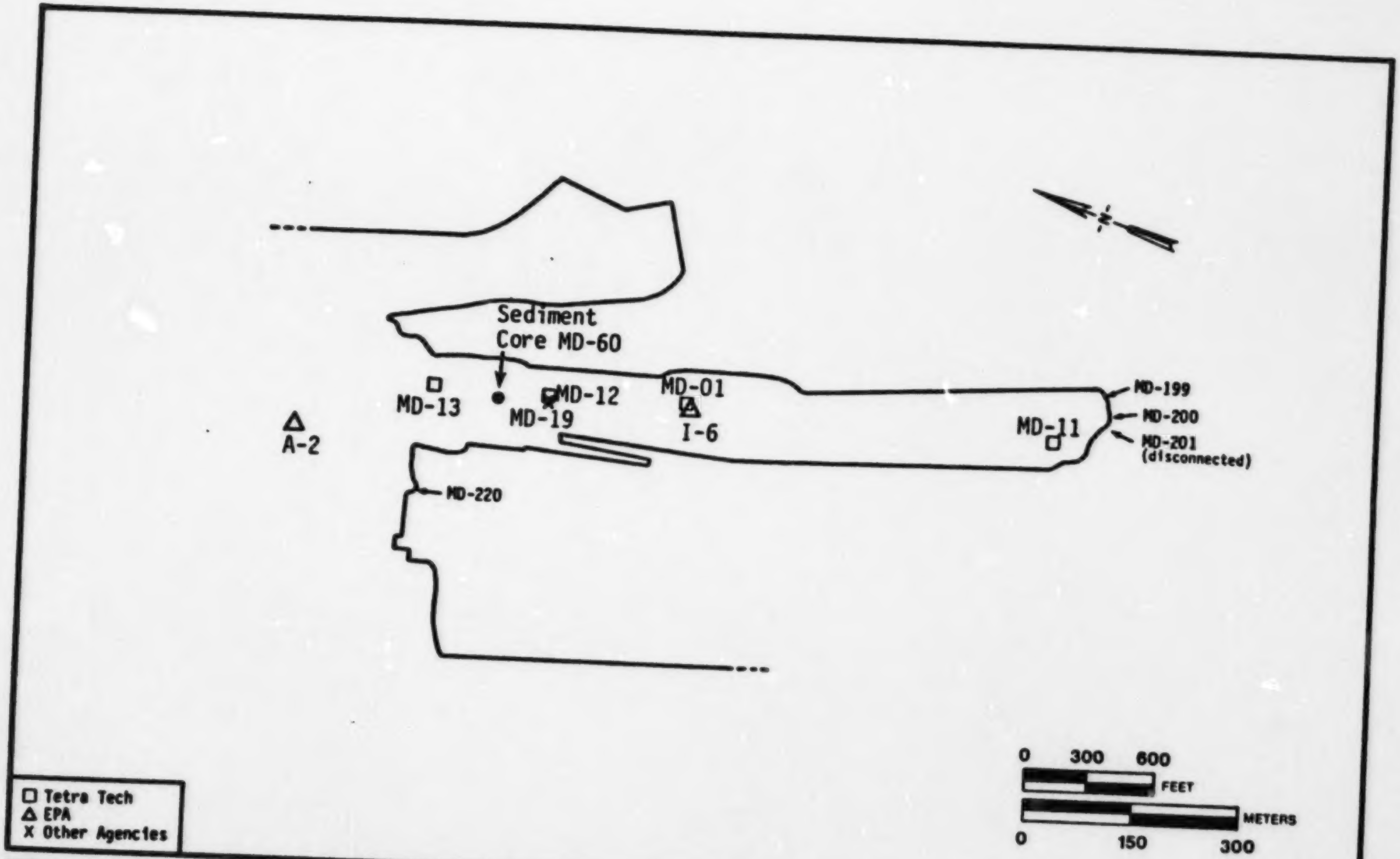

Sediment
Core MD-60
MD-13
MD-12
MD-19
MD-01
I-6
A-2
MD-11
MD-199
MD-200
MD-201
(disconnected)
MD-220
N
0
300
600
FEET
METERS
0
150
300
□ Tetra Tech
△ EPA
X Other Agencies

Figure 22. Surficial sediment and sediment core sampling station locations from all studies in Middle Waterway.

Paxport may also be a source of metals at the mouth of Middle Waterway because wood wastes containing ASARCO slag were used to fill a salmon enhancement area developed in 1982. According to the approved dredging permit, Paxport was to fill the salmon enhancement area with clean fill material. The U.S. EPA and the Corps of Engineers are currently planning enforcement action against Paxport for this violation of their dredging permit terms. Discharge of surface water runoff from MD-200 is the only confirmed source of metals to Middle Waterway. Any or all of the activities located along the Middle Waterway are potential sources of PAH, but no sources have been confirmed.

3.10.3.1 Unknown Sources--

Source identification was hindered by the lack of sampling data for the discharges and Middle Waterway. Contaminants for which additional source identification is necessary are mercury, copper, HPAH, arsenic, zinc, dichlorobenzenes, LPAH, pentachlorophenol, lead, 4-methylphenol, phenol, dibenzothiophene, diterpenoid hydrocarbons, and methylpyrenes. Champion International, Paxport, and Coast Craft are possible sources of pentachlorophenol, phenol, mercury and copper due to the use of these in the wood products industry as components in wood preservatives. Discharge of wood wastes from the Paxport and Champion Saw Mills and the storage of logs in the waterway by these companies may contribute to observed concentrations of 4-methylphenol (e.g., either directly or through a biodegradation process). Only MD-200 has been analyzed for this contaminant and none was detected on three separate occasions. All of the activities along Middle Waterway are potential sources of PAH. Due to the ubiquity of these contaminants and the absence of a clear concentration gradient within the waterway, confirmation of sources is impossible without additional investigation and sediment sampling.

A few possible scenarios exist for the metals contamination in Middle Waterway. First, the use of sandblasting grits and marine paints by Foss Launch and Tug, Marine Industries Northwest, and Cook's Marine Specialties may have contributed metals to the waterway. Metals loadings from these sources need further investigation. Second, a historical land use survey conducted by Dames and Moore (1982) indicated that ASARCO slag was placed at the southwest shore near the mouth of Middle Waterway. Confirmation could not be obtained regarding the physical state of the slag (i.e., whether it is fill or rip-rap). Groundwater contaminated with metals from the slag may be entering the waterway via groundwater seeps at discharges MD-202 and MD-203. Good correlation was seen in arsenic and zinc ratios of ASARCO slag, sediments along the Ruston-Pt. Defiance Shoreline, and sediments at the mouth of Middle Waterway. Copper concentrations were higher in sediments from the mouth of Middle Waterway, although this may be explained by copper loading from Champion International, which is a confirmed source of this metal. The third scenario is loading from the storm drains at the head of the waterway. MD-200 is a confirmed source of copper (0.0075 lb/day) and mercury (0.000053 lb/day). Calculated loadings from the storm drains at the head of the waterway are relatively small and spatial trends are patchy and do not indicate specific sources. Therefore, metals loadings to the Middle Waterway are most likely from a combination of the above sources and possibly some unidentified sources.

In the absence of confirmed sources of the priority contaminants, recommendation of specific remedial technologies is not possible at this time. Additional source identification is necessary in Middle Waterway. Recommendations for source identification include implementation of an industrial survey (particularly Foss Launch and Tug, Marine Industries Northwest, and Cook's Marine Specialties) to determine chemical usage and waste generation, sampling of discharges for priority contaminants, and sampling of additional sediments to determine the existence of contaminant gradients.

3.10.4 Sediment Remedial Actions

Sediments within Middle Waterway have been assigned an environmental significance ranking of 3 based on observed contamination, toxicity, and biological effects. Observed environmental effects were moderate and therefore this waterway has lower priority for sediment remedial action. Additionally, contaminant loading to Middle Waterway is ongoing, but confirmed sources and their respective loadings have not been determined. Consideration of sediment remedial action is not recommended until contaminant sources have been identified and controlled.

The volume of contaminated sediment within Middle Waterway is estimated to be 125,033 yd^3. This volume was estimated using a surface area of 31 ac, computed using a planimeter, and an average sediment depth of 2.5 ft, estimated from cross sections of Middle Waterway (Raven Systems and Research 1984). For the purpose of this preliminary volume calculation, contamination is assumed to extend through the soft sediment layer. It may, however, extend into the harder underlying sediment layers. Based on a low priority ranking for environmental effects and inconclusive source identification, Middle Waterway is not recommended for sediment remedial action at this time.

3.10.5 Data Needs

Several data needs were identified that hinder the development and evaluation of potential remedial alternatives for remedial alternatives for the problem area in Middle Waterway. Some data gaps are associated with non-definitive boundaries of the area of concern, while others are associated with the inconclusive identification of possible sources. Specific data needs for Middle Waterway include

- Additional source identification of priority contaminants, including

  Priority 2 - Mercury, copper
  Priority 3 - HPAH, arsenic, zinc, dichlorobenzenes, LPAH, pentachlorophenol, lead, 4-methylphenol, phenol, dibenzothiophene, diterpenoid hydrocarbons, methylpyrenes

- More precise definition of the spatial and vertical extent of contamination, if cost effective (i.e., to determine whether the area of concern is the entire waterway or two separate areas at the mouth and the head) by additional surface and deep core sampling of the sediments. This may not be necessary, unless sediment management technologies are considered for this problem area

- Characterization of the effluent from storm drains

- Determination of significance of contaminant loadings from Paxport, Coast Craft, and Champion International to the Middle Waterway from the discharge of wood wastes and/or wood treating products

- Evaluation of loadings of metals from sandblasting operations of Foss Launch and Tug, Marine Industries Northwest, and Cook's Marine Specialties; evaluation of the use and possible discharge of organic contaminants contained in solvents, strippers, paints, thinners, and degreasers from these facilities.

3.11 RUSTON-PT. DEFIANCE SHORELINE SEGMENT 3

3.11.1 Physical Description

Segment 3 of the Ruston-Pt. Defiance Shoreline extends from the Tacoma Yacht Club north along the shore, in front of Pt. Defiance Park (Figure 5). Facilities located along Segment 3 include the Tacoma Yacht Club and the Pt. Defiance Ferry Terminal. There are no known discharges to this segment of the Ruston-Pt. Defiance Shoreline. However, the drainage investigation performed by the Tacoma-Pierce County Health Department (TPCHD) did not extend north of ASARCO property. The recent subbottom profiling that was performed as part of the Commencement Bay Nearshore/Tideflats Remedial Investigation did not extend through the problem area off Pt. Defiance (Raven Systems and Research 1984). Sediments along the Ruston-Pt. Defiance Shoreline are typically sands, averaging less than 20 percent fine-grained material, and having a clay content of 5 percent.

3.11.2 Extent of Contamination

Results of the Commencement Bay Nearshore/Tideflats Remedial Investigation indicate that arsenic, cadmium, copper, zinc, lead, N-nitrosodiphenylamine, and antimony are priority 2 contaminants. There were no priority 1 or priority 3 contaminants identified in the Segment 3 problem area off Pt. Defiance. Definition of this problem area was based on chemical and biological analyses of sediment samples collected at Stations RS-22 and RS-24 (Figure 6). Sediment bioassays indicated significant amphipod toxicity at Station RS-24. No taxonomic characterization was performed on sediment samples from this problem area. Significant copper accumulations were present in the muscle tissues of fishes collected along the Ruston-Pt. Defiance Shoreline.

3.11.3 Contaminant Sources

The metals contamination in the problem area defined within Segment 3 off Pt. Defiance is believed to be associated exclusively with slag or spilled ore because of the granular nature of the sediments. The peninsula enclosing the Tacoma Yacht Basin, located immediately south of the problem area, was formed by copper smelting slag placed there under permits issued from 1917 to 1962. The shoreline adjacent to the Tacoma Yacht Club (to the south), on which the ASARCO plant is located, has also been built up with slag. The source of N-nitrosodiphenylamine is unknown, additional source investigation is necessary into possible sources of this compound or its precursors. N,N-dimethylaniline (DMA) was used by ASARCO to remove sulfur dioxide from stack emissions. WDOE inspectors documented the poor conditions of storage facilities for this substance, which has been observed leaking beneath the subfloor of the storage building. Samples of surface water showed high concentrations of DMA in drainage water beneath and near the storage building. Outfalls RS-003 (north) and RS-005 (south) are the most likely surface water routes to Commencement Bay (Pierce, R., 6 August 1985, personal communication). In addition to contaminated surface waters, WDOE suspects DMA may be leaching into the groundwater. It was not determined whether this compound occurs in sediments off ASARCO. Under appropriate acidic conditions, N,N-dimethylaniline (DMA) could be converted to p-nitroso-N,N-dimethylaniline or to an azo compound. The p-nitroso compound is not similar in structure to the N-nitrosodiphenylamine found in sediments off ASARCO. The conversion of DMA to N-nitrosodiphenylamine is not chemically feasible because it would require substitution of the methyl groups in the stable tertiary amine.

3.11.4 Sediment Remedial Actions

Sediments in the problem area defined in Segment 3 off Pt. Defiance have been assigned an environmental significance ranking of 1, based on observed contaminant levels, toxicity, and biological effects. Because of the relatively low environmental risk associated with these sediments, this problem area should receive low priority for evaluation of sediment remedial action. However, if sediment removal is considered for this problem area, source control remedial actions may be necessary to stabilize the slag, used extensively along this portion of the shoreline to prevent further sediment contamination by decomposing slag.

3.11.5 Data Needs

Data needs associated with the problem area in the Ruston-Pt. Defiance Shoreline Segment 3 are generally applicable if sediment remedial actions are being evaluated. Except for N-nitrosodiphenylamine, the source of the contaminants has been identified as ASARCO, and it is believed that contaminant transport mechanisms are well defined for this problem area. Data needs specific to the problem area off Pt. Defiance include

- Additional source identification for N-nitrosodiphenylamine; investigation of possible sources of this compound or its precursors
- Analyze for N,N-dimethylaniline (DMA) in sediments off ASARCO
- More precise definition of spatial extent by surface sediment sampling (only necessary if evaluating sediment remedial actions)
- More precise definition of vertical extent by deep sediment coring (only necessary if evaluating sediment remedial actions).

3.12 CITY WATERWAY SEGMENT 3

3.12.1 Physical Description

Segment 3 of City Waterway extends from the 11th Street Bridge (approximately 3,500 ft from the mouth of the waterway) to the mouth of the waterway. Facilities located along the east bank are Puget Sound Plywood, the "D" Street petroleum facilities, Fick Foundry, Olympic Chemical, and Globe Machine. Totem Marina is located along the west shore (Figure 23). There are four permitted discharges to City Waterway Segment 3 and 19 unpermitted discharges (Figure 10). Facilities with NPDES permits are the "D" Street facilities [Union Oil Company (No. WA0000728), Mobil Oil Corporation (No. WA000387), and Shell Oil Company (No. WA0001210)] and Fick Foundry (No. WA0037851).

City Waterway Segment 3 is approximately 3,500 ft in length and 750 ft wide. Totem Marina extends nearly 300 ft into the waterway from the west shore, which greatly reduces the actual navigable portion. The depth of City Waterway in Segment 3 increases from the 11th Street Bridge to the mouth of the waterway. Recent subbottom profiling of City Waterway Segment 3 showed mid-channel depths ranging from 30 ft below MLLW at 11th Street to 35 ft below MLLW at the mouth (Raven Systems and Research 1984). Sediment accumulation within Segment 3 is from 1 to 4 ft. A cross section of City Waterway near the 11th Street Bridge shows a fairly uniform soft sediment layer from 2 to 3 ft thick. Another cross section immediately north of Totem Marina shows localized sediment deposition, up to 4 ft deep, in what appears to be dredge scars (Raven Systems and Research 1984). Sediments within City Waterway are typically 64 percent fine-grained material with an average clay content of 18 percent. There are no proposed dredging projects in City Waterway Segment 3. The Corps of Engineers has not dredged City Waterway since 1948. The only other dredging project in Segment 3 has been Superior Oil Company in 1983.

3.12.2 Extent of Contamination

Results of the Commencement Bay Nearshore/Tideflats Remedial Investigation indicate that HPAH and LPAH are priority 2 contaminants in City Waterway Segment 3; PCBs, zinc, phenol, biphenyl, and dibenzothiophene are priority 3 contaminants. There were no priority 1 contaminants identified within Segment 3. A potential hot spot was defined near the mouth of City Waterway, including Stations CI-20 and CI-21 (Figure 24). High levels (but below AET) of 2-methoxyphenol were present in sediments from the mouth of the waterway, and may have resulted from transport into the waterway from the St. Paul Waterway problem area. With the exception of PAH, which had elevated concentrations in this area above their toxicity and benthic AET, most other chemicals detected appeared to be part of a gradient of decreasing concentrations from the middle or head of City Waterway. Sediment bioassays indicated oyster larvae and amphipod toxicity. Fish analyses showed significant accumulation of PCBs in muscle tissue.

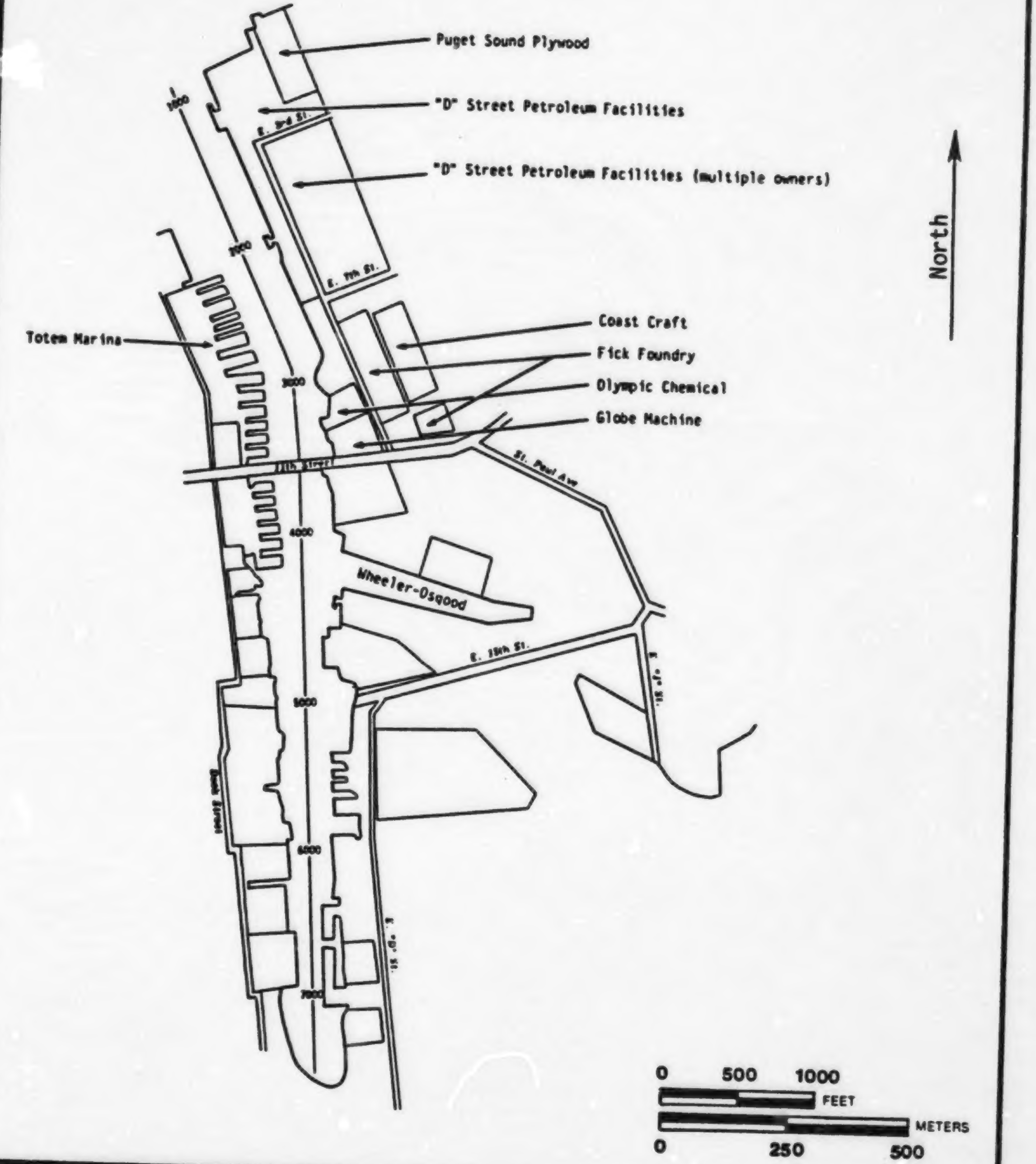

Puget Sound Plywood
"D" Street Petroleum Facilities
"D" Street Petroleum Facilities (multiple owners)
North
Totem Marina
Coast Craft
Fick Foundry
Olympic Chemical
Globe Machine
E. 3rd St.
E. 7th St.
11th Street
St. Paul Ave
Wheeler-Osgood
E. 15th St.
E. "G" St.
E. "D" St.
Dock Street
1000
2000
3000
4000
5000
6000
7000
0
500
1000
FEET
METERS
0
250
500

Figure 23. Industries surrounding City Waterway Segment 3.

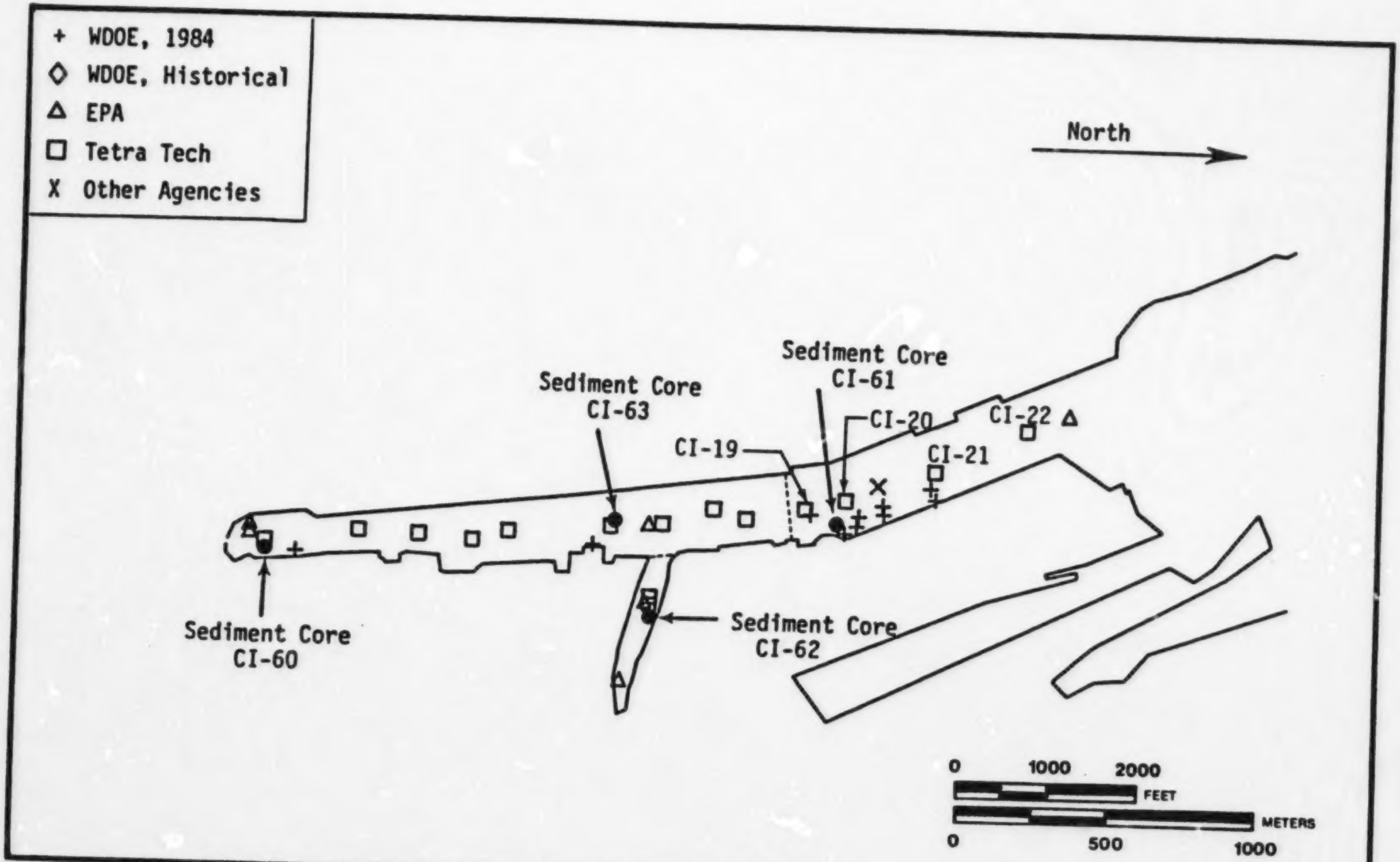

+ WDOE, 1984
◇ WDOE, Historical
△ EPA
□ Tetra Tech
X Other Agencies
North
Sediment Core CI-61
Sediment Core CI-63
CI-19
CI-20
CI-22
CI-21
Sediment Core CI-60
Sediment Core CI-62
0
1000
2000
FEET
METERS
0
500
1000

Figure 24. Surficial sediment and sediment core sampling station locations from all studies in City Waterway.

3.12.3 Contaminant Sources

Attempts to identify contaminant sources in City Waterway Segment 3 have been unsuccessful. In a study of the "D" Street petroleum facilities as a possible source of PAH and other organic contaminants to City Waterway (Johnson and Norton 1985b), WDOE inspectors compared contaminant concentrations in groundwater collected from interceptor wells near the bulk storage facilities with contaminant concentrations in the sediments adjacent to the "D" Street facilities. The WDOE concluded that petroleum product entering City Waterway from the "D" Street facilities is not significantly contributing to the observed sediment contamination. LPAH, benzene, ethylbenzene, toluene, and xylenes were the major contaminants identified in groundwater contaminated by petroleum products. LPAH compounds detected in sediments adjacent to the "D" Street facilities did not match those found in the groundwater contaminated by petroleum product. HPAH were one of the major contaminants identified in City Waterway sediments. HPAH are typically associated with combustion products, and not raw petroleum product. Although the "D" Street facilities have not been proven to be a major source of contaminants to City Waterway Segment 3, improvement of the storage and distribution systems at the "D" Street facilities is recommended to minimize the release of petroleum product into the environment. Sources of HPAH, LPAH, PCBs, phenol, biphenyl, and dibenzothiophene to City Segment 3 have not been identified. Additional source identification is necessary for all priority contaminants within City Waterway Segment 3 prior to delineation of potential remedial technologies.

3.12.4 Sediment Remedial Action

Sediments in City Waterway Segment 3 have been assigned an environmental significance ranking of 3, based on observed contaminant levels, toxicity, and biological effects. Contaminant sources for this problem area have not been identified. Therefore, remedial action for these sediments is not recommended at this time.

3.12.5 Data Needs

Several missing pieces of information prevent the identification of contaminant sources to City Waterway Segment 3 and the evaluation of appropriate remedial technologies. Potential source control remedial technologies cannot be identified until additional source information is available. Remedial action for sediments within City Waterway Segment 3 is not recommended until sources have been identified and controlled. Specific data needs for the problem area in City Waterway segment 3 include

- Additional source identification for the priority contaminants within this problem area, including

  Priority 2 - HPAH, LPAH
  Priority 3 - PCBs, zinc, phenol, biphenyl, dibenzothiophene

- Thorough inspection of the "D" Street petroleum facilities to identify locations within the storage and distribution system where petroleum product is being released into the environment

- Vertical extent of contamination by deep sediment coring (may only be necessary if sediment remedial actions are being evaluated for this problem area)
- Investigation of Totem Marina as a potential source of PAH
- Investigatation of storm drains as potential contaminant sources.

3.13 SUMMARY

The success of source control remedial actions within the problem areas of Commencement Bay is dependent on accurate and complete identification of all major sources of the problem chemicals to those problem areas. The degree to which this has been accomplished for each problem area varies greatly. In general, additional source investigations are required in all problem areas for at least some of the problem chemicals prior to evaluation of sediment remedial actions. Additionally, sedimentation rates within individual waterways have not been measured, and therefore the potential recovery time (i.e., coverage with clean sediments) for a problem area cannot be determined, assuming the sources of the problem chemicals can be controlled. In most problem areas, the vertical extent of contamination was not adequately determined. Typically, sediment cores did not reach background levels of problem contaminants in the bottom horizons. Definition of the vertical extent of contamination is necessary for evaluation of sediment removal technologies and may also provide guidance for management of an areawide dredging plan.

Potential remedial technologies were not identified for problem areas in Segments 3, 4, and 6 of Hylebos Waterway, Blair Waterway, or Ruston-Pt. Defiance Shoreline Segment 1. These areas were all given a low priority for remedial action because the environmental significance was relatively low (except for RSS1a), the spatial extent was small (less than 10 ac in surface area), and contaminant sources could not be identified with any confidence. The problem areas in Hylebos Waterway Segments 3, 4, and 6, and Blair Waterway contained stations where contaminants exceeded AET, but no confirming biological data were available. Milwaukee Waterway contained no chemicals above their AET. The problem area in Ruston-Pt. Defiance Shoreline Segment 1 is a single station "hot spot" whose spatial extent was not well defined. Source evaluation was conducted for this problem area, and it was concluded that the observed contamination is most likely from a historical source. Therefore, potential source control remedial technologies were not identified for this problem area.

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APPENDIX A

LAND AND STORM DRAIN OWNERSHIP IN THE COMMENCEMENT BAY NEARSHORE/TIDEFLATS STUDY AREA

A

LAND AND STORM DRAIN OWNERSHIP IN THE COMMENCEMENT BAY NEARSHORE/TIDEFLATS STUDY AREA

Occupant	Owner	Owner's Address	Tax Lot Number
CITY WATERWAY			
American Plating	L. R. Jones	4 Forest Glen Blvd. SW Tacoma, WA	895000-176-0 -177-0 -178-0 -179-0 -180-0
Chevron	Chevron USA Inc.		03-20-04-4-002
City Marina Facilities	City Marina Inc.	Marshall W. Perro 1616 E. D St. Tacoma, WA	
"D" Street Petroleum Facilities	Superior Oil Co.	P.O. Box 24447 Terminal Annex Seattle, WA	895000-066-1
"D" Street Petroleum Facilities (multiple owners)	Puget Sound Plywood Inc.		637500-008-0 -006-1
	Union Oil Co. of California		637500-009-3
	Shell Oil Co.		637500-005-0
	Mobil Oil Corp.		637500-011-0 -006-0
Fick Foundry	Fick Foundry	2203 C St. Tacoma, WA 98401	637500-014-1
Hygrade Foods	Hygrade Foods	P.O. Box 1636 Tacoma, WA	03-20-04-4-004
Martinac Shipbuilding	Martinac Shipbuilding	401 E. 15th Tacoma, WA 98421	03-20-04-1-017
Northern Pacific Plywood	Burlington Northern Railroad	P.O. Box 38 Graham, WA	895000-191-0 -190-0
St. Regis Door Mill (closed)	The Wattley Co.	29314 11th Pl. S. Federal Way, WA	895000-405-1

Puget Sound Plywood	Puget Sound Plywood	230 E. F St. Tacoma, WA	895000-061-0 -064-0
Tacoma Spur	Tacoma Spur	1401 A St. Tacoma, WA	03-20-04-2-011
Tar Pits Site	Simon & Sons B.N.R.R. Union Pacific R.R. Hygrade		
Totem Marina	R. W. Bright	P.O. Box 3532 Lacey, WA	895000-217-1
	Moorage Associates	P.O. Box 1001 Bellevue, WA 98009	895000-218-1 895000-208-1
Union Pacific & Burlington Northern Railroads	Union Pacific & Burlington Northern Railroads		
West Coast Grocery	West Coast Grocery	1525 E. D St. Tacoma, WA	895000-167-0 -166-0 -165-0 -164-0 -169-1 -170-0 -171-3
Western Fish	Burlington Northern Railroad	2100 Interstate Center 999 3rd Avenue Seattle, WA 98104-1105	895000-197-1
Woodworth & Co.	Woodworth & Co., Inc.	1200 E. D St. Tacoma, WA	895000-106-0 -120-0
Surface Water Drains			
CI-225	City of Tacoma	747 Market Street Tacoma, WA 98401	N/A
CI-230	"		N/A
CI-234	"		N/A
CI-243	"		N/A
CI-245	"		N/A
CI-248	"		N/A
CI-237	"		N/A
CS-237	"		N/A
CW-254	"		N/A
CI-703	Harmon Furniture		N/A
CI-236	Atlas Foundry		N/A

HYLEBOS WATERWAY

Cascade Timber Yard No. 1	McFarland & Cascade	P.O. Box 1496 Tacoma, WA	03-21-26-4-005
Cascade Timber Yard No. 2	Port of Tacoma	P.O. Box 1837 Tacoma, WA 98401	
Dunlap Towing	Dunlap Towing	P.O. Box 593 LaConner, WA 98257	
General Metals Inc.	Leslie Sussman	1 N. Stadium Way #6 Tacoma, WA	03-21-36-2-032 -033 -037 -038 -051 -053
Jones Chemical Inc.	Ulto Pricola	100 Sunny Sol Blvd. Caledonia, NY 14423	03-21-36-2-409
Kaiser Aluminum & Chemical Corporation	Kaiser Aluminum & Chemical Corporation	P.O. Box 24471 Oakland, CA	03-21-36-3-013
Louisiana Pacific	Louisiana Pacific	P.O. Box 1936 Tacoma, WA 98401	03-21-36-4-024
Murray Pacific Yard No. 1	Pan Pacific	3502 Lincoln Ave. Tacoma, WA	03-21-35-1-039
Occidental Chemical Corporation	Occidental Petroleum Co.	P.O. Box 868 Houston, TX	
Pennwalt Chemical Corporation	Pennwalt Chemical Corporation	2901 Taylor Way Tacoma, WA	03-21-35-1-041
Sound Refining Inc.	Sound Refining	2628 Marine View Dr. Tacoma, WA	03-21-26-4096
Tacoma Boatbuilding	Tacoma Boatbuilding	184 Marine View Dr. Tacoma, WA 98401	03-21-36-1-800 -801 -2-045
Wasser-Winters	Port of Tacoma	P.O. Box 1837 Tacoma, WA 98401	03-21-36-4-017 -026

Weyerhaeuser	Weyerhaeuser	3401 Taylor Way Tacoma, WA 98477	03-21-36-2-046
Surface Water Drains HY-052	Kaiser Aluminum and Chemical Corp.	P.O. Box 24471 Oakland, CA	N/A
HY-054	"	"	N/A

MIDDLE WATERWAY

Champion International	Champion International	P.O. Box 2133 Tacoma, WA 98401	895000-126-2 -052-5
Coast Craft	Wes Ohlson	1002 E. F St. Tacoma, WA	895000-076-0 -088-0
Cooks Marine Specialties	Dillingham Corp.	c/o Foss Launch & Tug Co. 660 Wing St. Seattle, WA	895000-074-1
Foss/Dillingham	Dillingham Corp.	c/o Foss Launch & Tug Co. 660 Wing St. Seattle, WA	895000-074-2
Foss Tug	Dillingham Corp.	c/o Foss Launch & Tug Co. 660 Wing St. Seattle, WA	895000-074-4
Marine Industries Northwest	Dillingham Corp.	c/o Foss Launch & Tug Co. 660 Wing St. Seattle, WA	895000-074-3
Surface Water Drain MD-200			N/A

RUSTIN-PT. DEFIANCE SHORELINE

American Smelting & Refining Co.	American Smelting & Refining Co.	P.O. Box 1677 Tacoma, WA	895000-337-0 022123-100-0 023650-006-7
Tacoma North Sewage Treatment Plant	City of Tacoma	747 Market St. Tacoma, WA 98402	

Surface Water Drains			
RS-002	City of Ruston		N/A
RS-040	City of Ruston		N/A

SITCUM WATERWAY

Port of Tacoma	Port of Tacoma	P.O. Box 1837 Tacoma, WA 98401	
Port of Tacoma Sealand	Port of Tacoma	P.O. Box 1837 Tacoma, WA 98401	
Surface Water Drains			
SI-172	City of Tacoma	747 Market St. Tacoma, WA 98402	N/A
SI-175	"		
SI-716	"		
SI-176	Port of Tacoma	P.O. Box 1837 Tacoma, WA 98401	N/A
SI-717	"		
SI-718	"		
SI-719	"		

ST. PAUL WATERWAY

Champion International	Champion International	P.O. Box 2133 Tacoma, WA 98401	895000-052-3